



THE SPD PROJECT AT NICA

Alexey Guskov

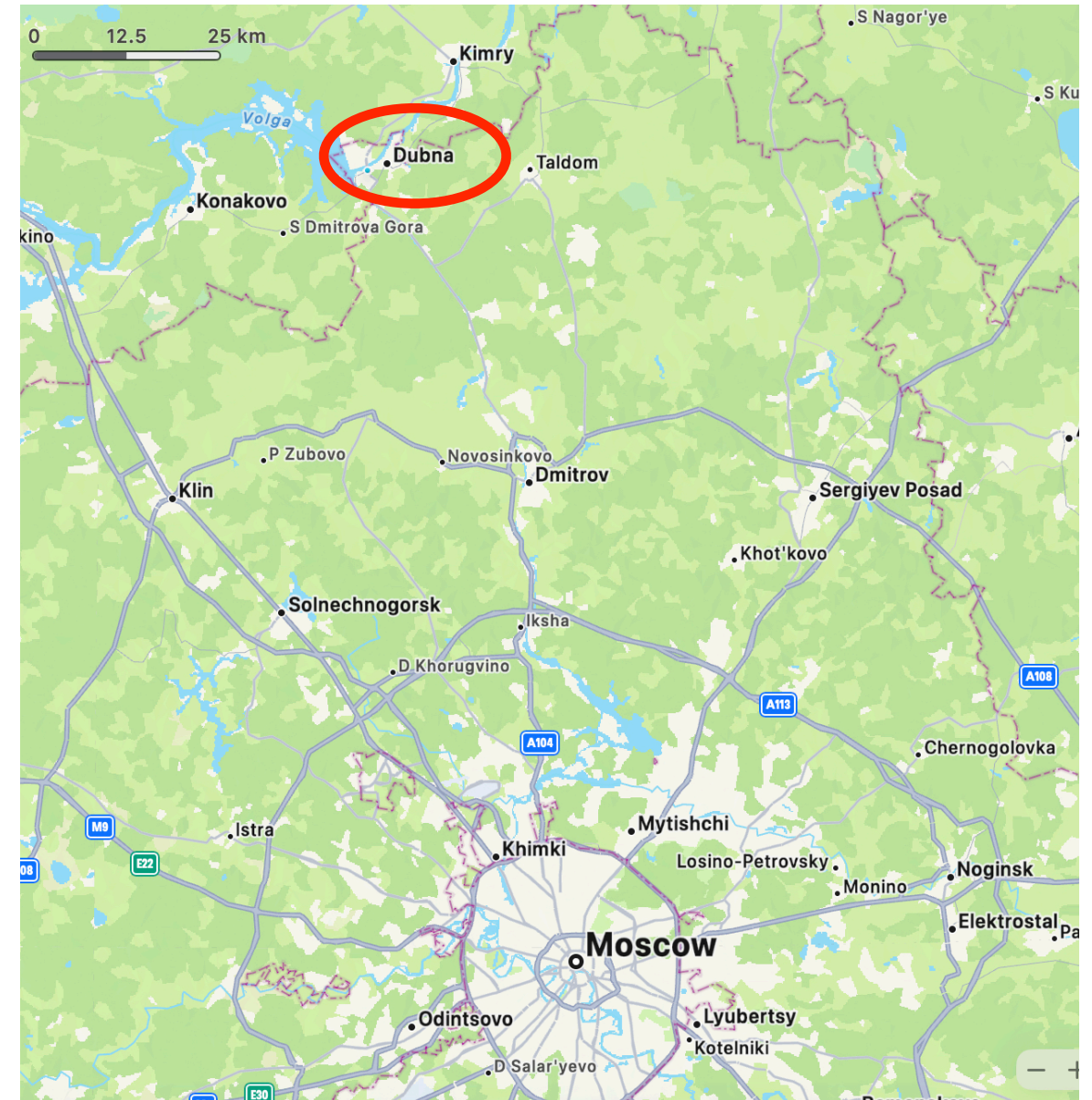
**Joint Institute for Nuclear Research, Dubna
on behalf of the SPD Collaboration**

avg@jinr.int

26.09.2025



THE JOINT INSTITUTE FOR NUCLEAR RESEARCH, DUBNA, RUSSIA

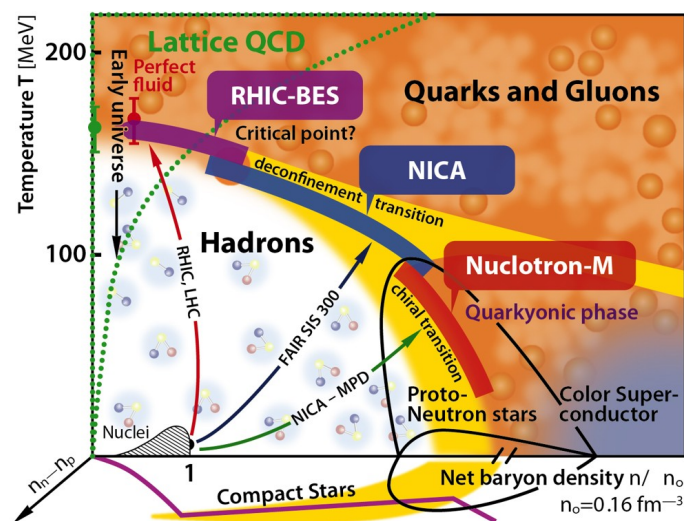


The **Joint Institute for Nuclear Research** is an international intergovernmental scientific research organization in the science city Dubna of the Moscow region (Russia)



NICA facility at JINR

NICA (Nuclotron-based Ion Collider fAcility)

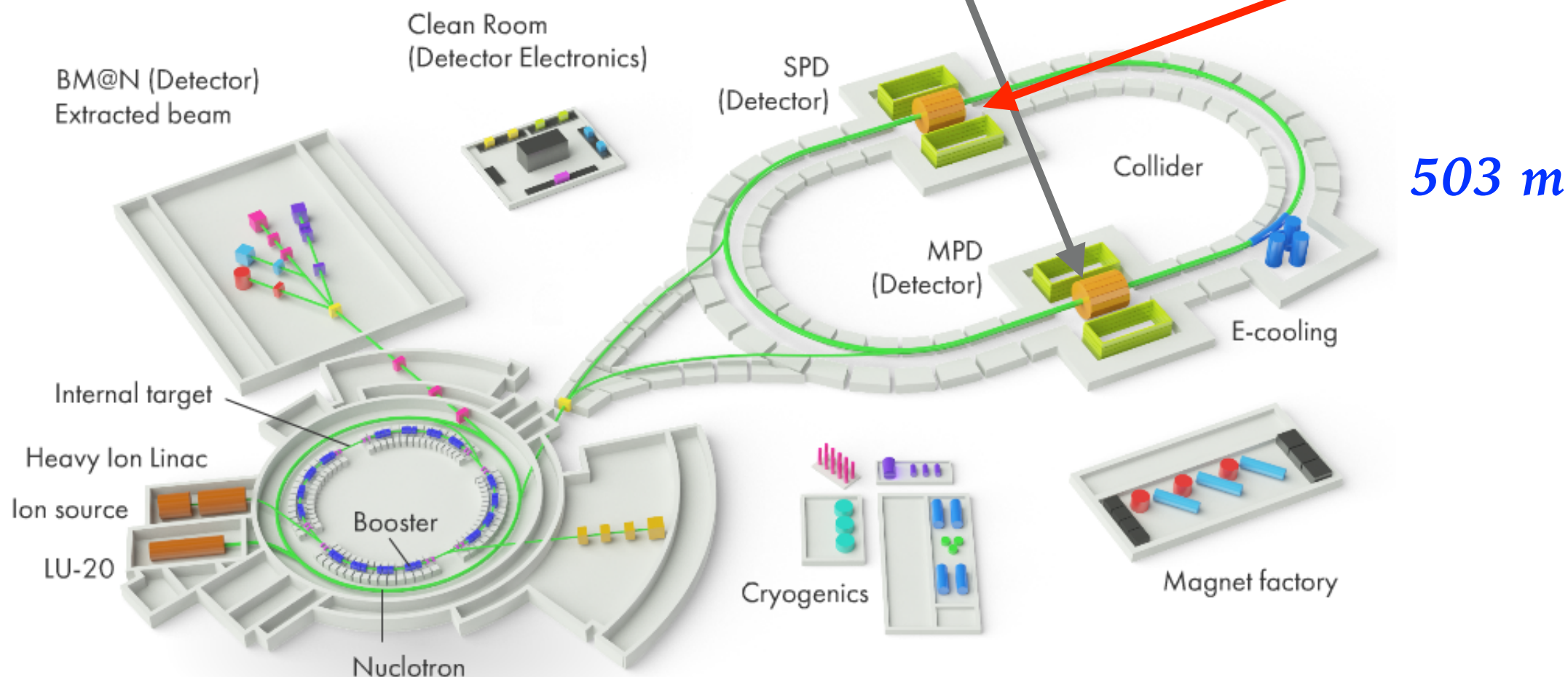


Stage 1

*Hot hadronic matter
in extremal conditions
with heavy-ion beams*

Stage 2

*Proton and deuteron
spin structure with
polarized beams*



NICA for spin physics

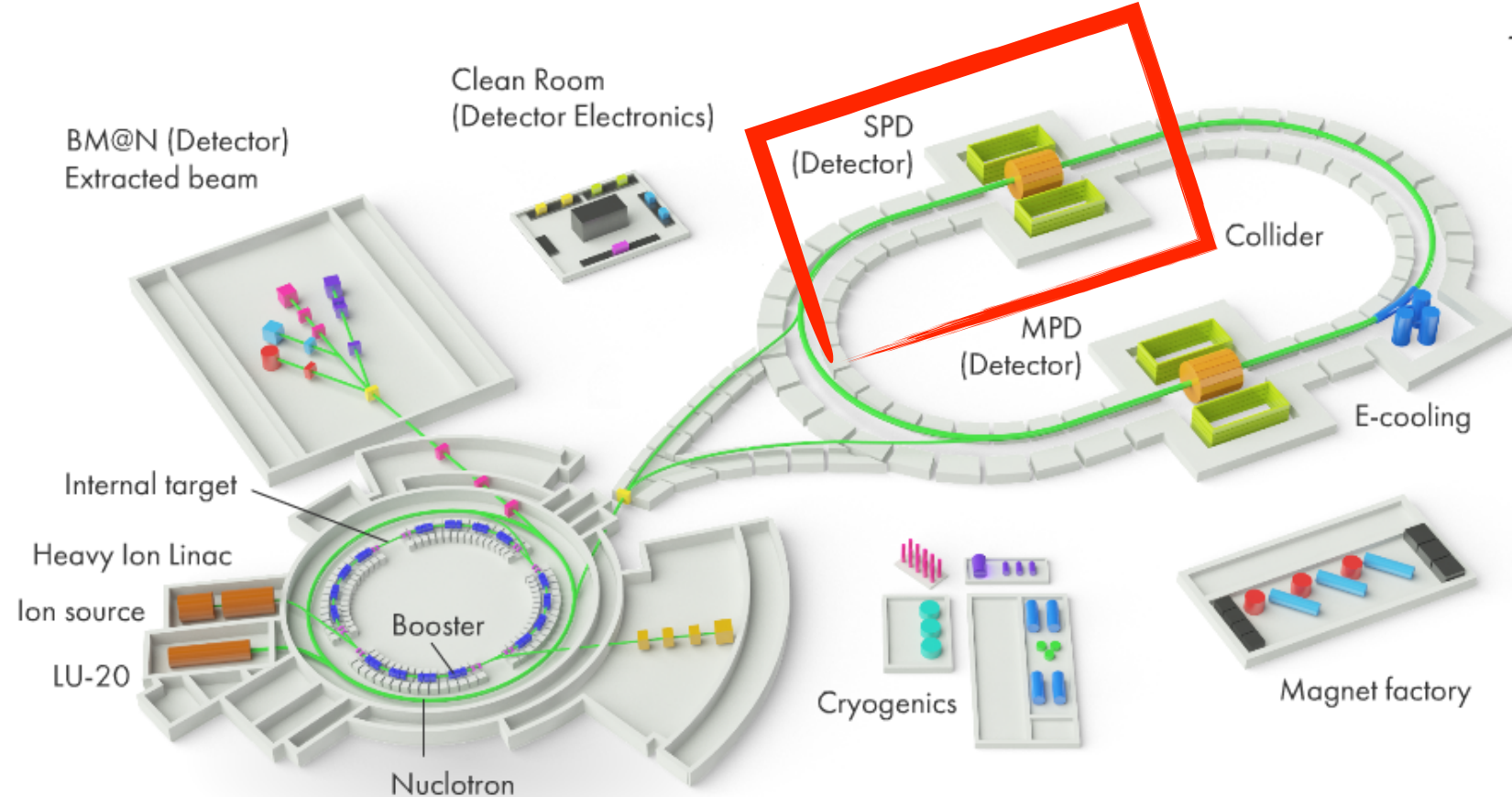
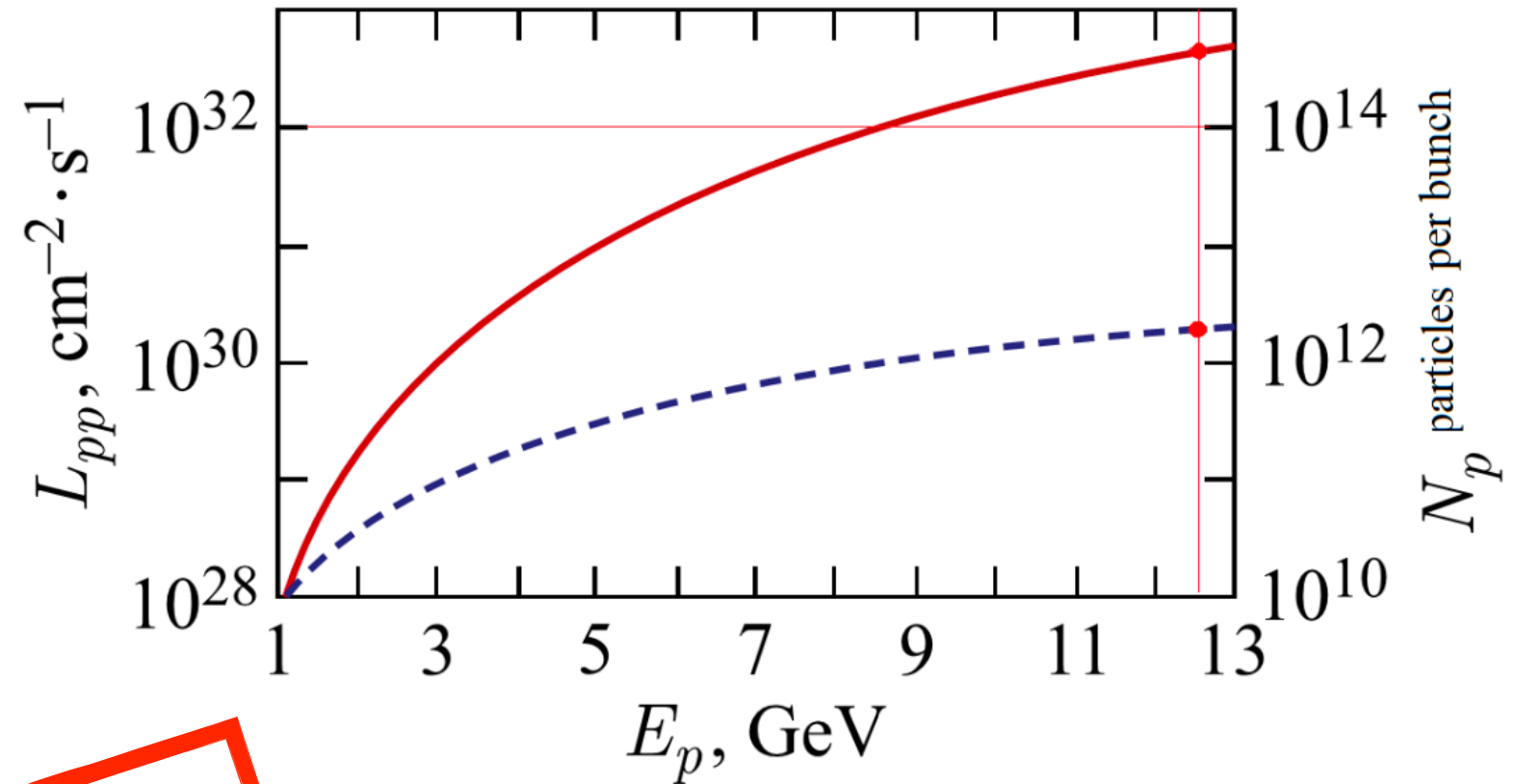
Polarized proton and
deuteron beams:

$$p^\uparrow p^\uparrow : \sqrt{s} \leq 27 \text{ GeV}$$

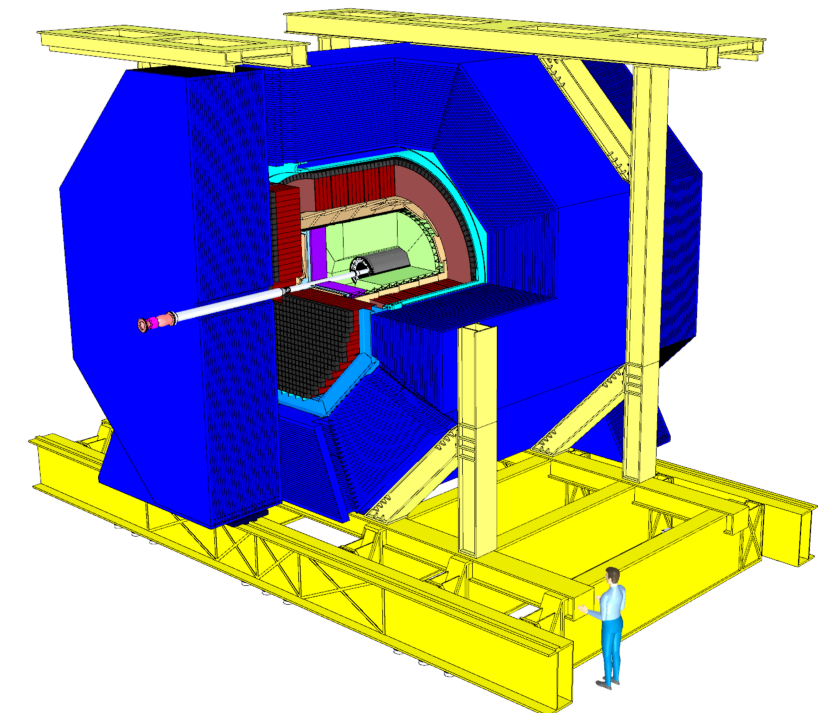
$$d^\uparrow d^\uparrow : \sqrt{s} \leq 13.5 \text{ GeV}$$

$$U, L, T \quad |P| > 70\%$$

Polarized ^3He beams are also
possible



Spin Physics Detector



NICA landscape



NICA landscape

- 13.6.24 - NICA technological launch
- 2025 - first run of the NICA complex
- First beam - end of 2025

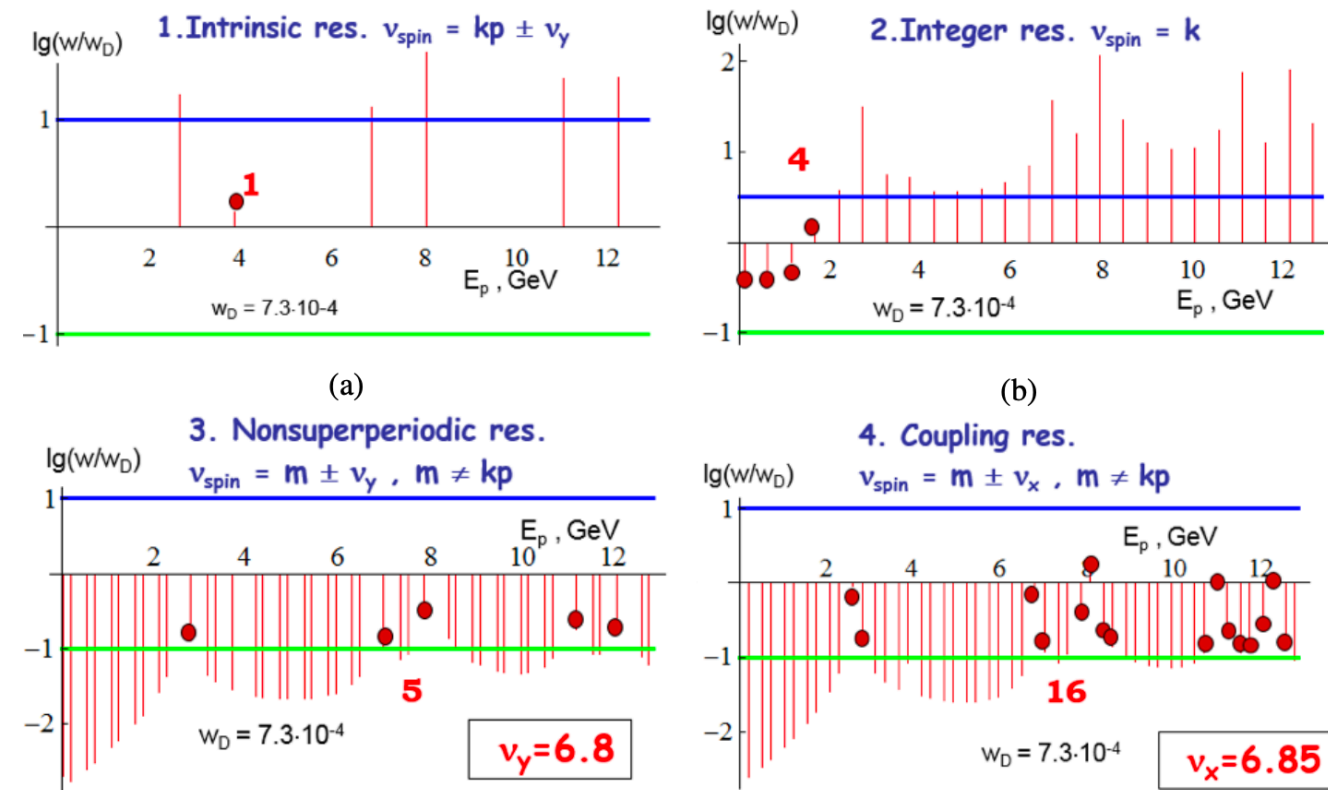


Polarized beams at NICA

$d\uparrow$ - was accelerated in 1986 (Synchrophasotron) and 2002 (Nuclotron). It is quite simple procedure: there is just 1 depolarizing **spin resonance at 5.6 GeV**.

$p\uparrow$ - was **first** obtained only in 2017.

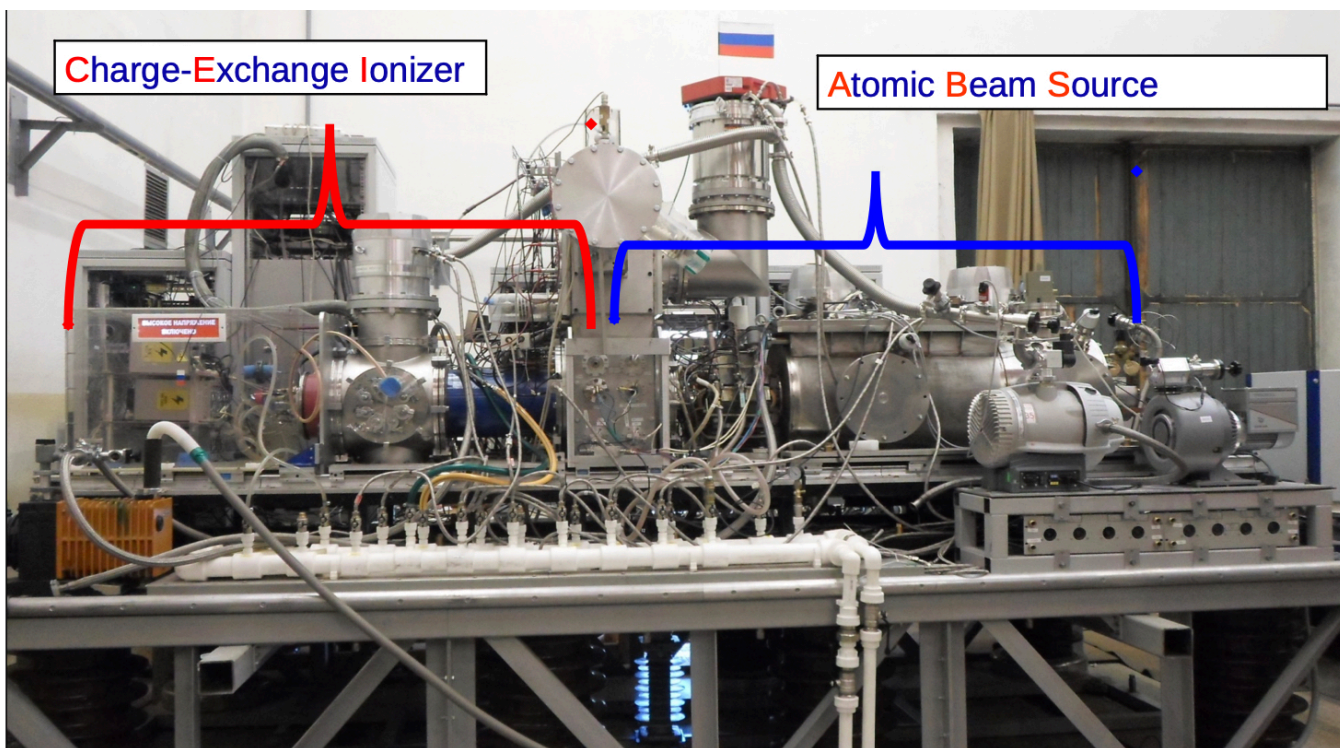
Source of Polarized Ions:



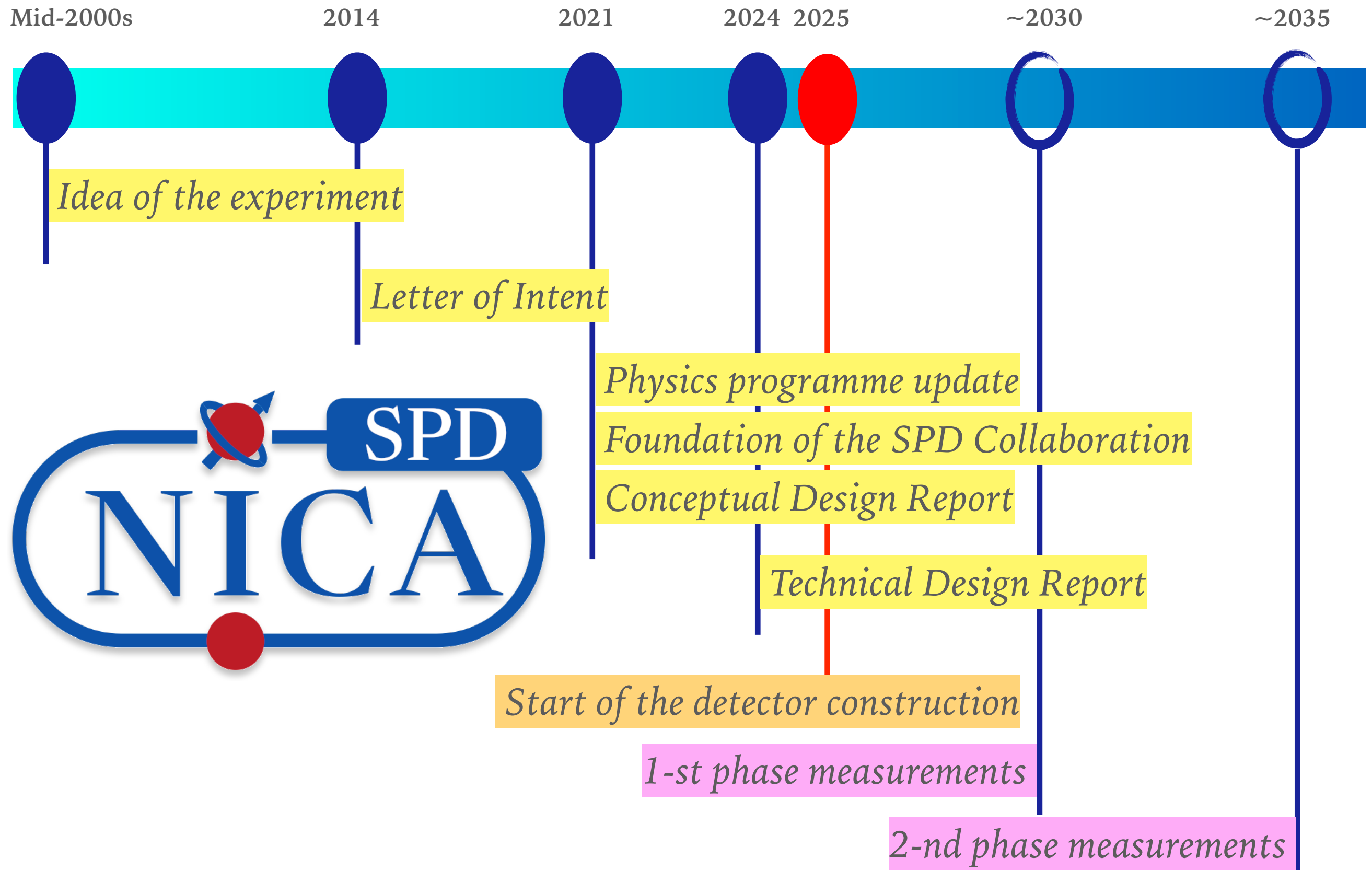
■ Longitudinal polarization in the IP can be supported at the integer spin-resonances

- ◆ For protons: $E_{kin} = (0.108 + 0.523 \cdot n)$ [GeV]
- ◆ For deuterons: $E_{kin} = (5.62 + 6.56 \cdot n)$ [GeV/u]

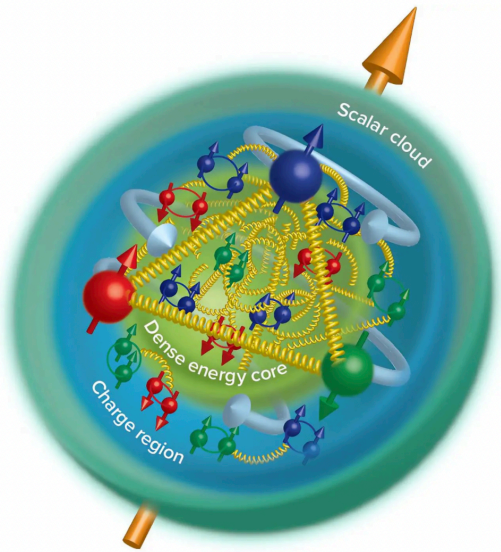
■ Transverse polarization at any energies



Spin Physics Detector project

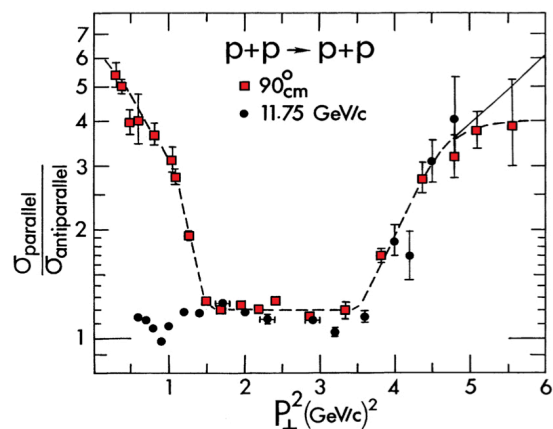
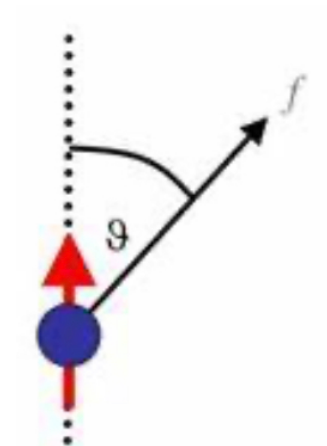


Physics @ SPD



- *Gluon polarized PDFs (TMDs and helicity)*
- *Quark polarized PDFs*
- *Deuteron tensor PDFs*

- *Spin effects in hadroproduction*
- *Polarization of hyperons and charmonia*
- *Spin correlations*



- *Other spin-dependent phenomena*

- *Unpolarized physics*

SPD gluon physics programme



Contents lists available at [ScienceDirect](#)

Progress in Particle and Nuclear Physics

journal homepage: www.elsevier.com/locate/ppnp



Review

On the physics potential to study the gluon content of proton and deuteron at NICA SPD

A. Arbuzov^a, A. Bacchetta^{b,c}, M. Butenschoen^d, F.G. Celiberto^{b,c,e,f},
U. D'Alesio^{g,h}, M. Deka^a, I. Denisenko^a, M.G. Echevarriaⁱ, A. Efremov^a,
N.Ya. Ivanov^{a,j}, A. Guskov^{a,k,*}, A. Karpishkov^{l,a}, Ya. Klopot^{a,m}, B.A. Kniehl^d,
A. Kotzinian^{j,o}, S. Kumano^p, J.P. Lansberg^q, Keh-Fei Liu^r, F. Murgia^h,
M. Nefedov^l, B. Parsamyan^{a,n,o}, C. Pisano^{g,h}, M. Radici^c, A. Rymbekova^a,
V. Saleev^{l,a}, A. Shipilova^{l,a}, Qin-Tao Song^s, O. Teryaev^a

^a Joint Institute for Nuclear Research, 141980 Dubna, Moscow region, Russia

^b Dipartimento di Fisica, Università di Pavia, via Bassi 6, I-27100 Pavia, Italy

^c INFN Sezione di Pavia, via Bassi 6, I-27100 Pavia, Italy

^d II. Institut für Theoretische Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

^e European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*), I-38123 Villazzano, Trento, Italy

^f Fondazione Bruno Kessler (FBK), I-38123 Povo, Trento, Italy

^g Dipartimento di Fisica, Università di Cagliari, I-09042 Monserrato, Italy

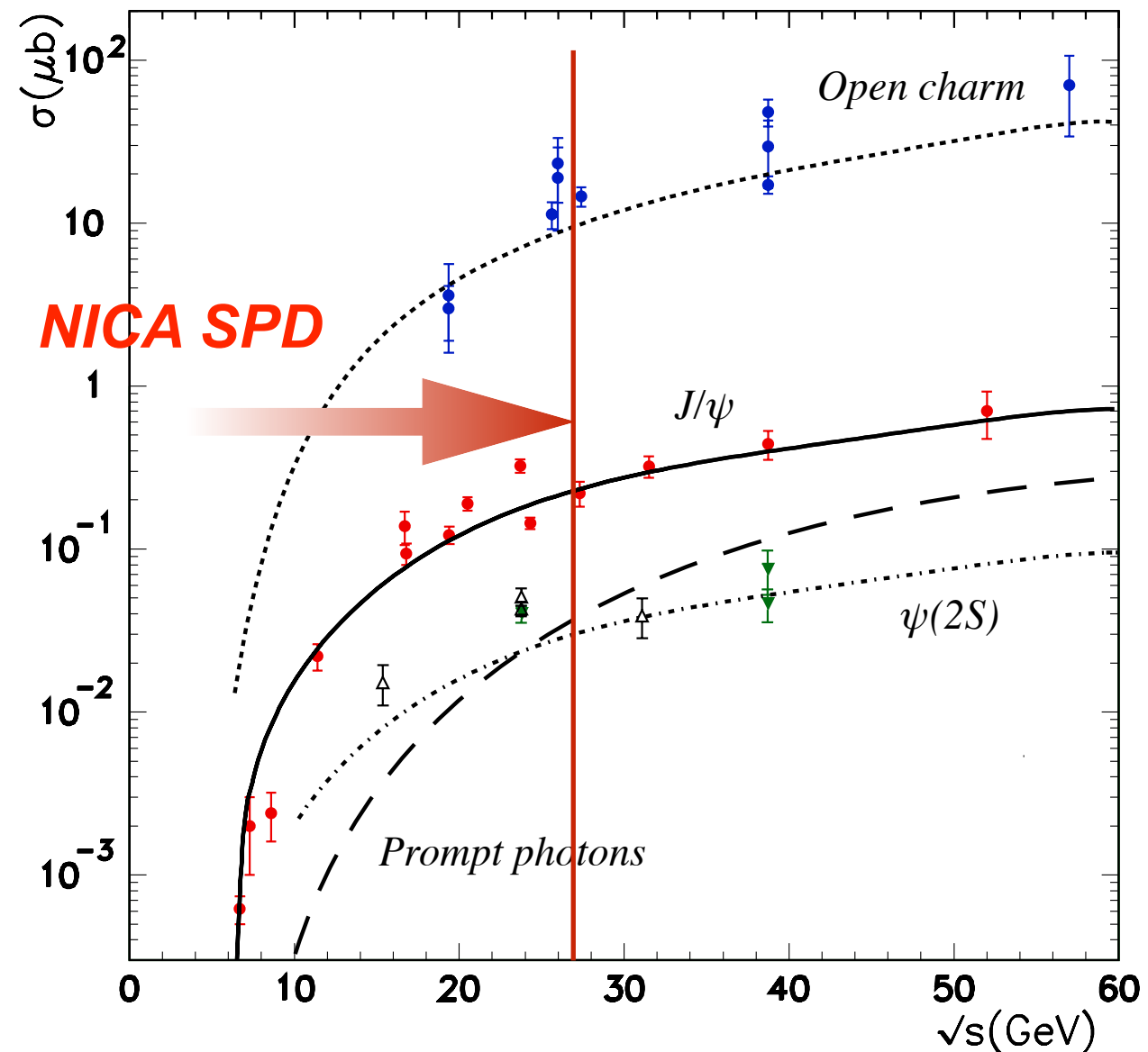
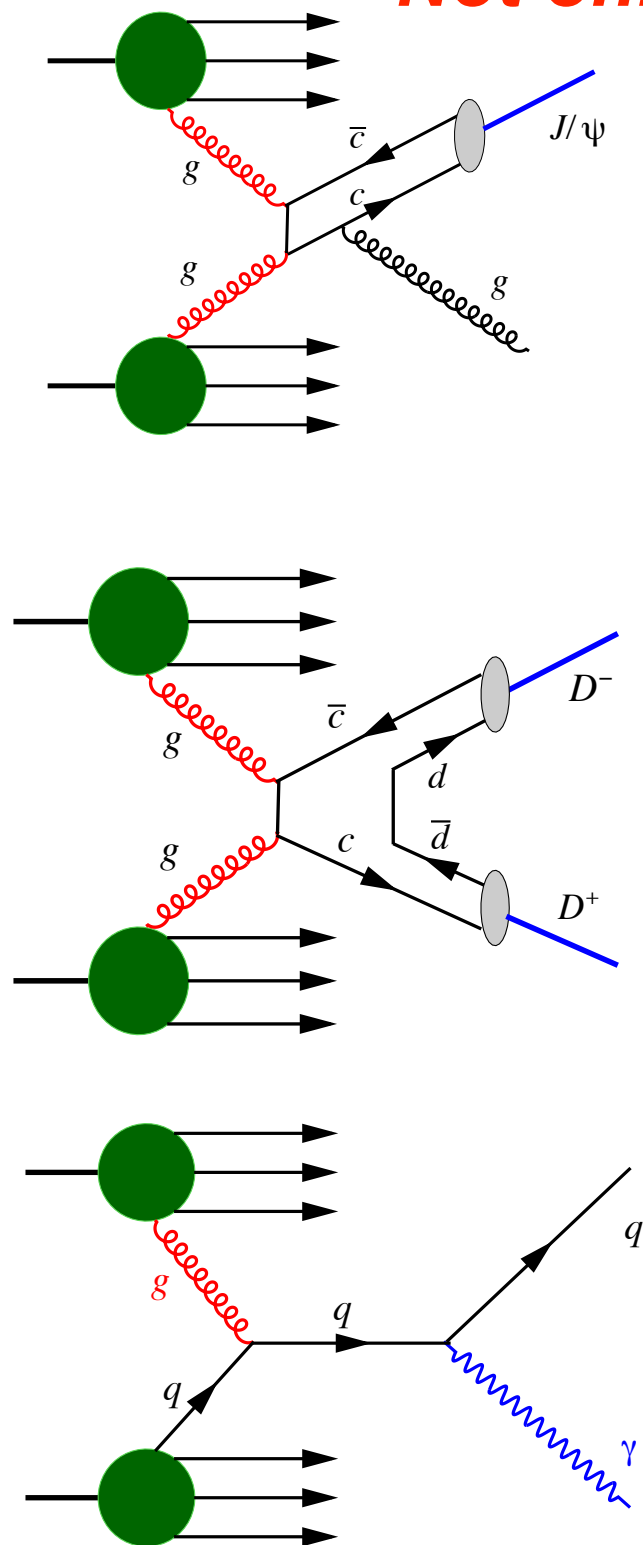
^h INFN Sezione di Cagliari, I-09042 Monserrato, Italy

Prog.Part.Nucl.Phys. 119 (2021) 103858

[arXiv:2011.15005](#)

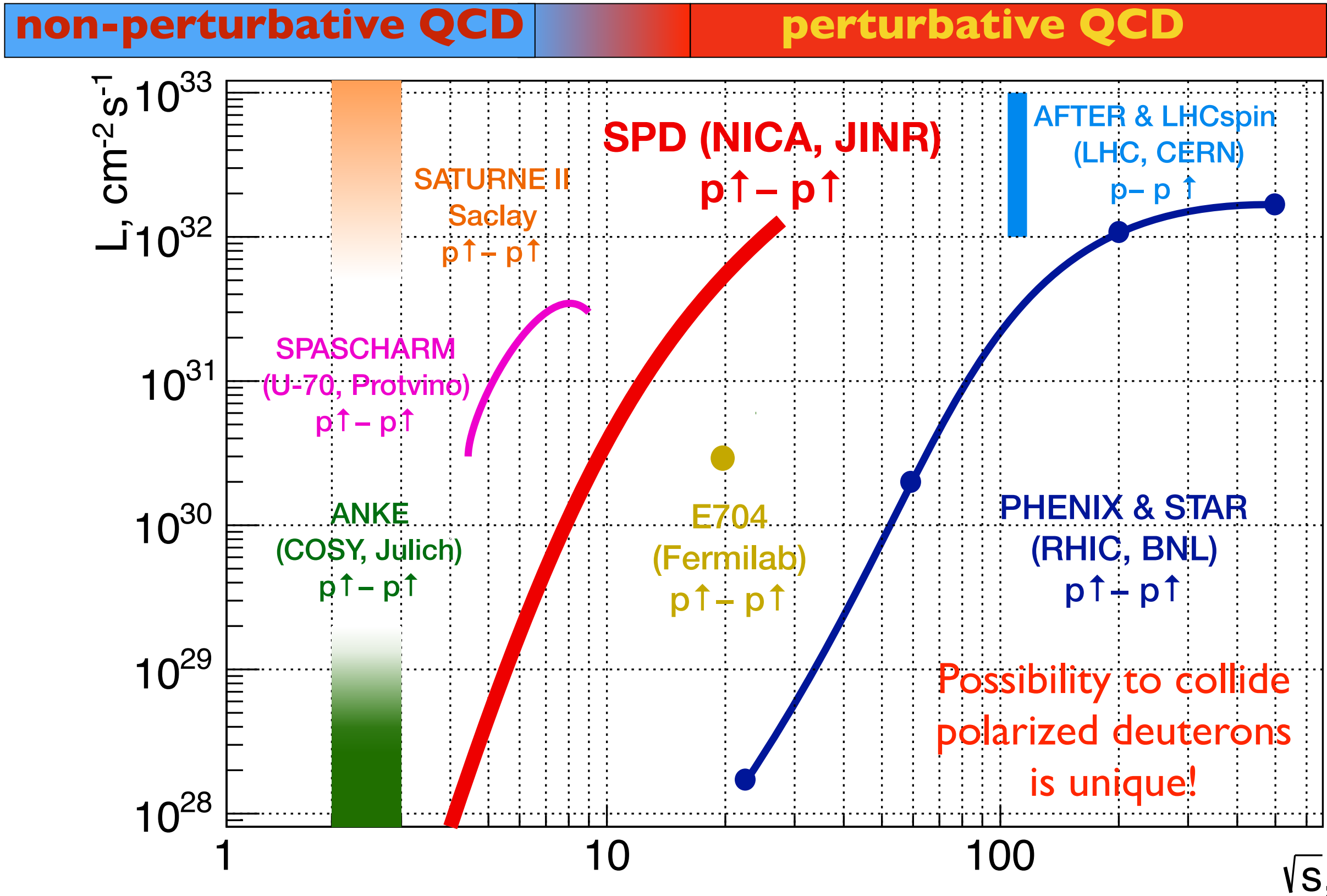
SPD *golden probes*

Not only J/ψ !

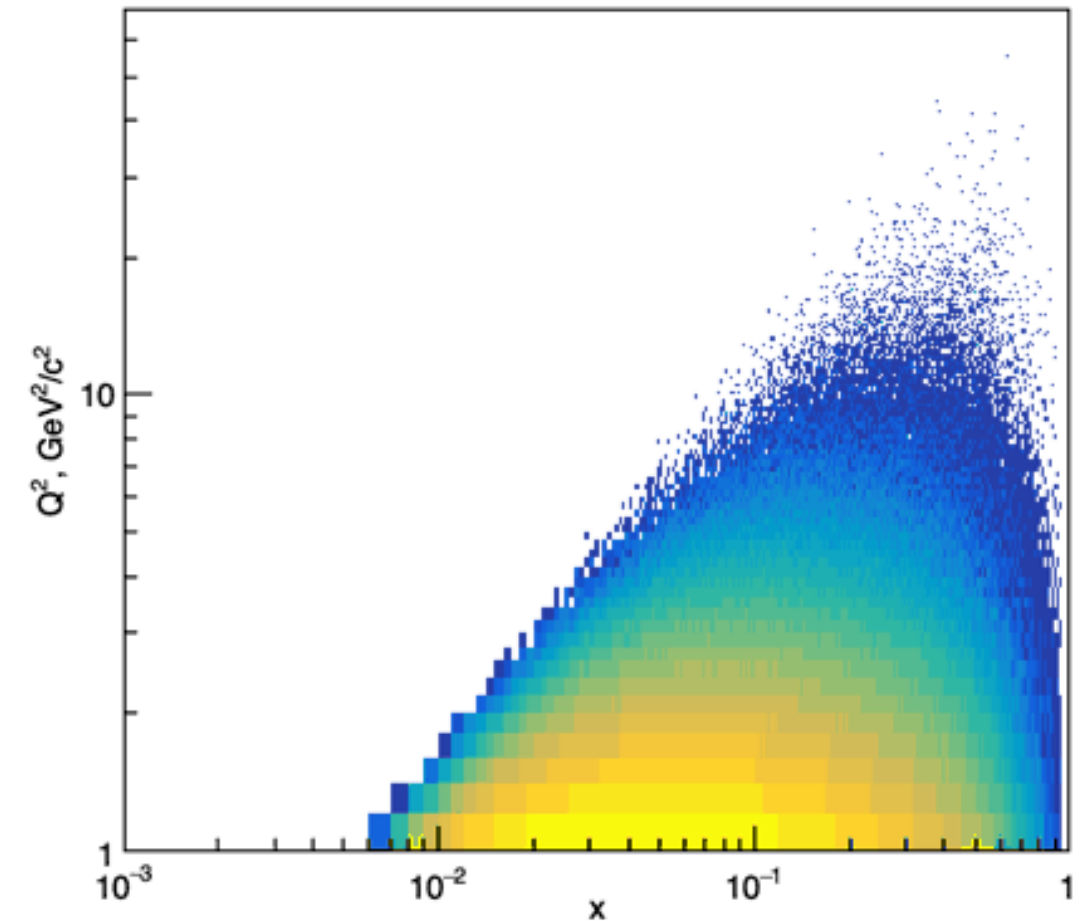
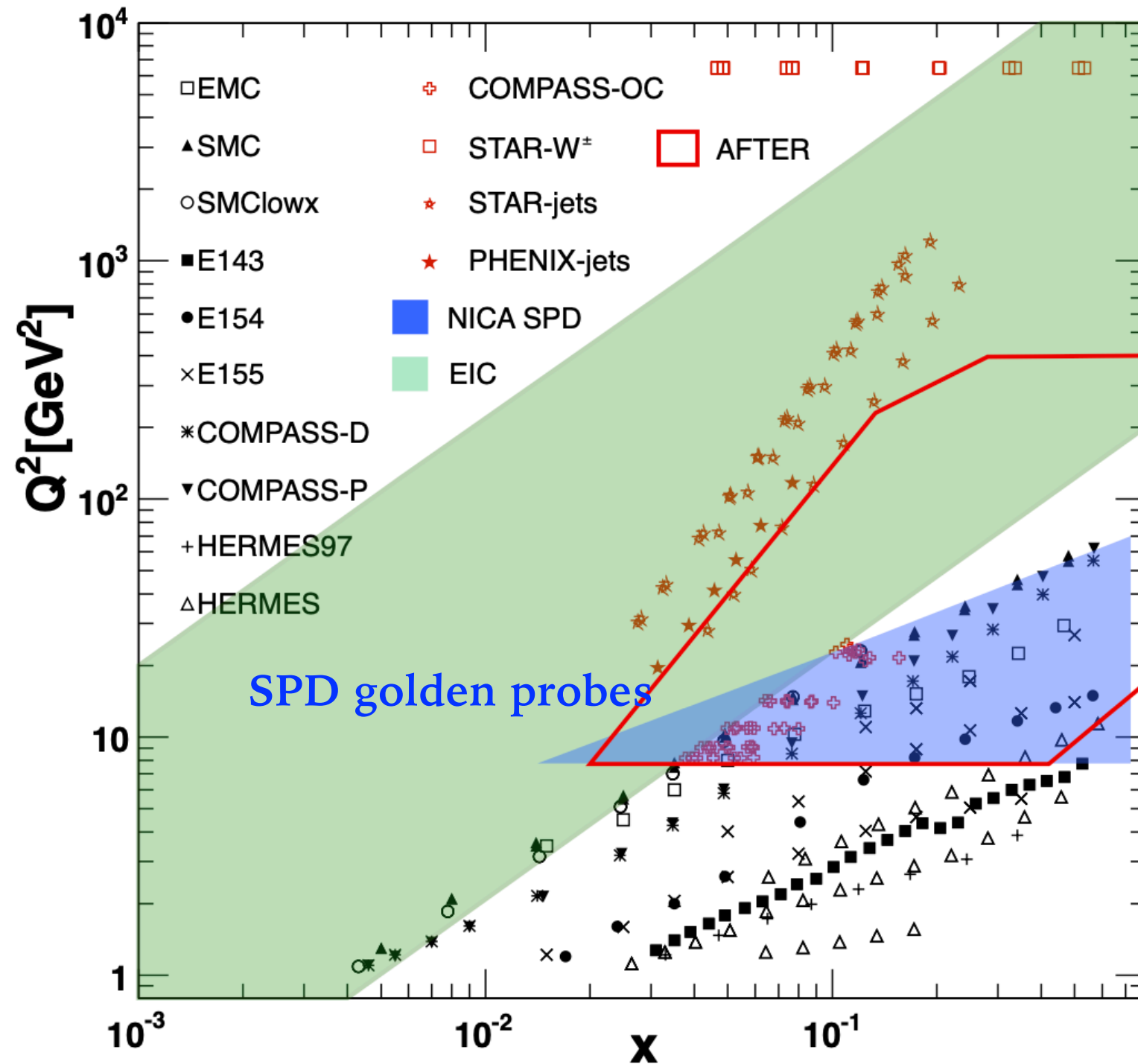


These golden probes define the layout of the SPD experimental setup.

SPD and other polarized pp exps



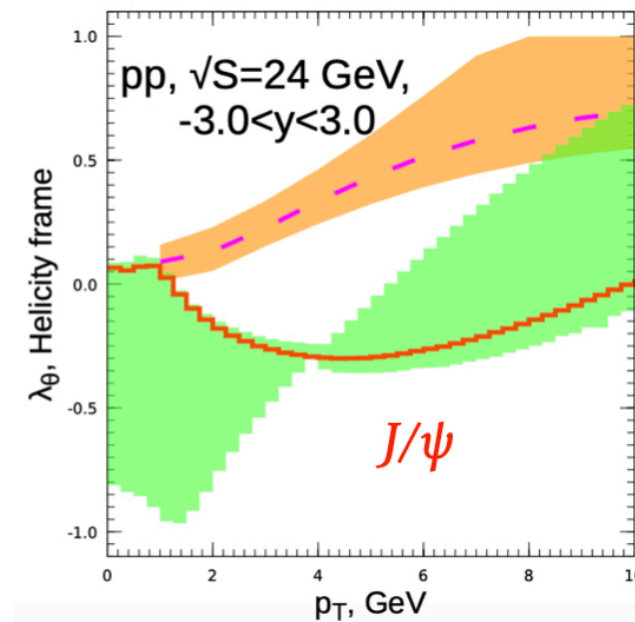
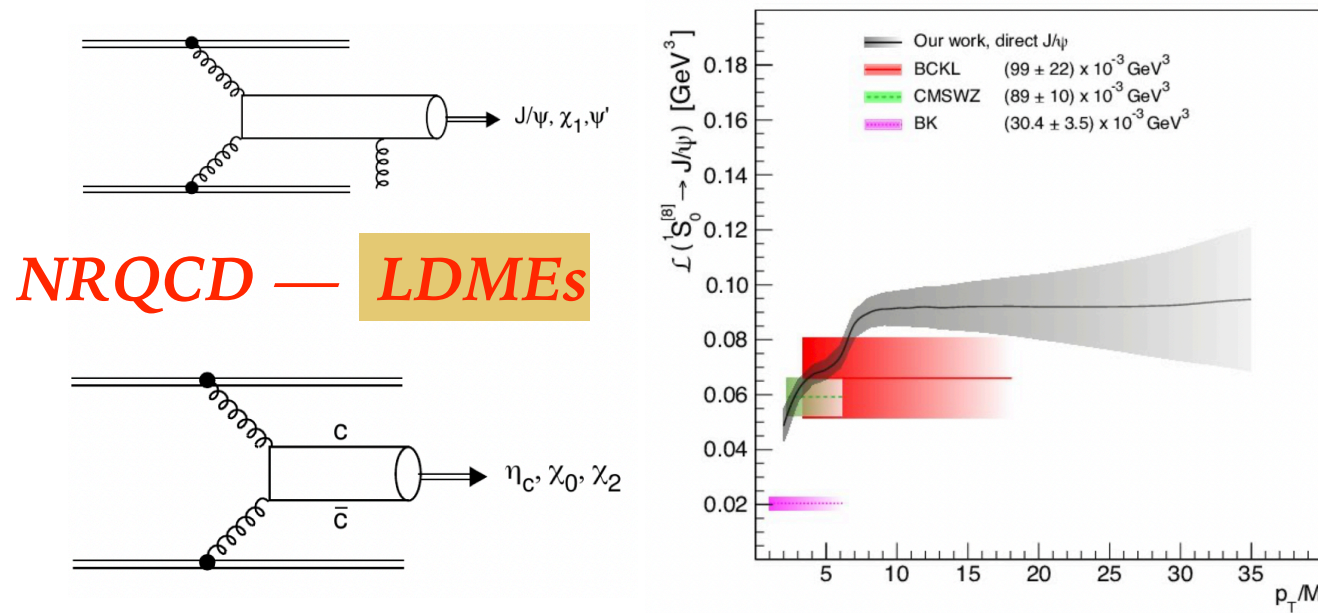
SPD and others



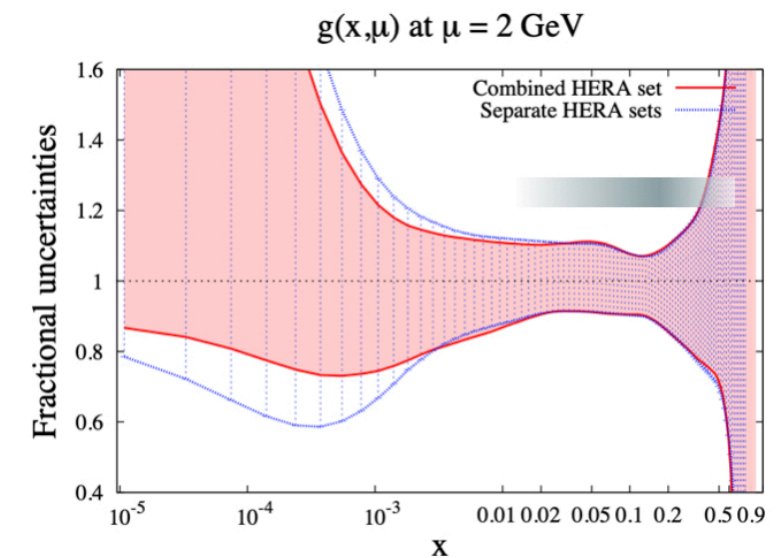
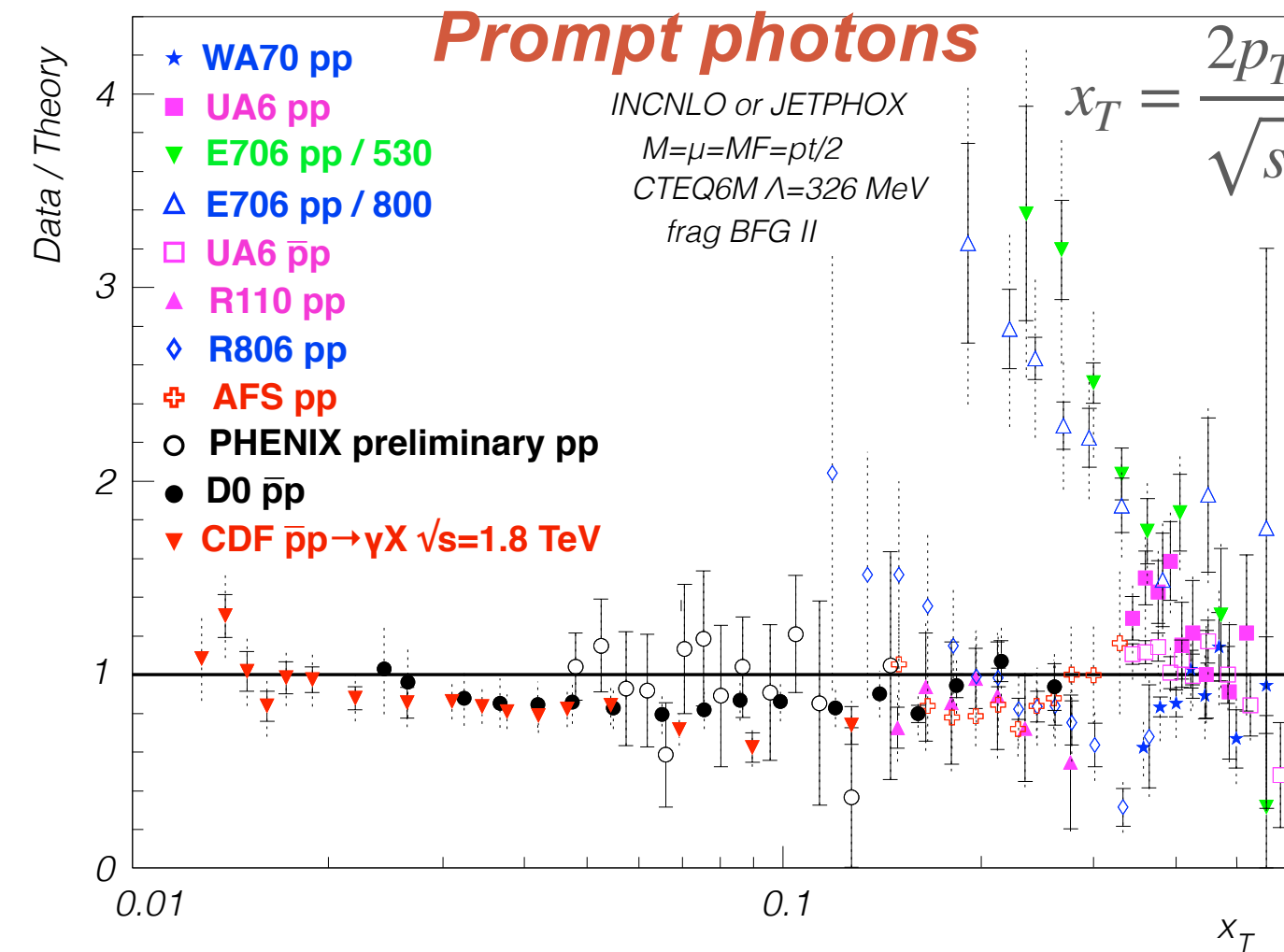
$$Q^2 = 1 \text{ GeV}^2/c^2, \langle x \rangle = 0.16$$

$$Q^2 = 10 \text{ GeV}^2/c^2, \langle x \rangle = 0.3$$

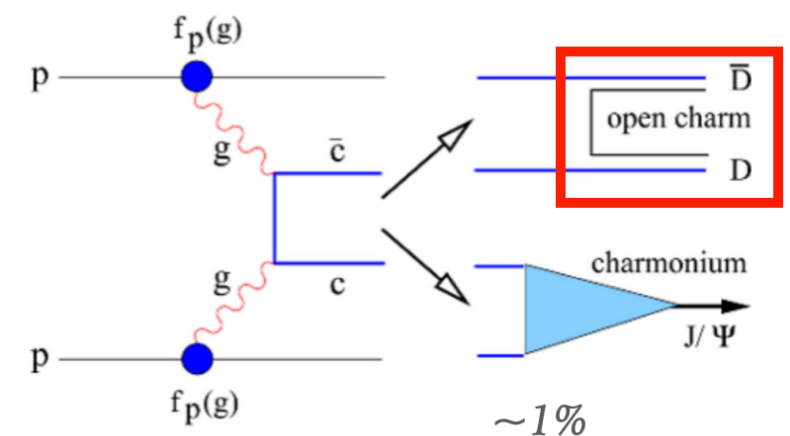
Unpolarized production



Charmonia

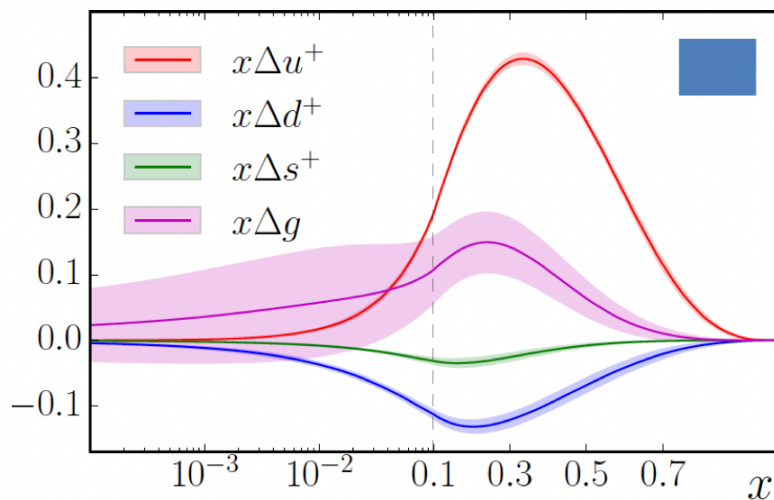


Open charm

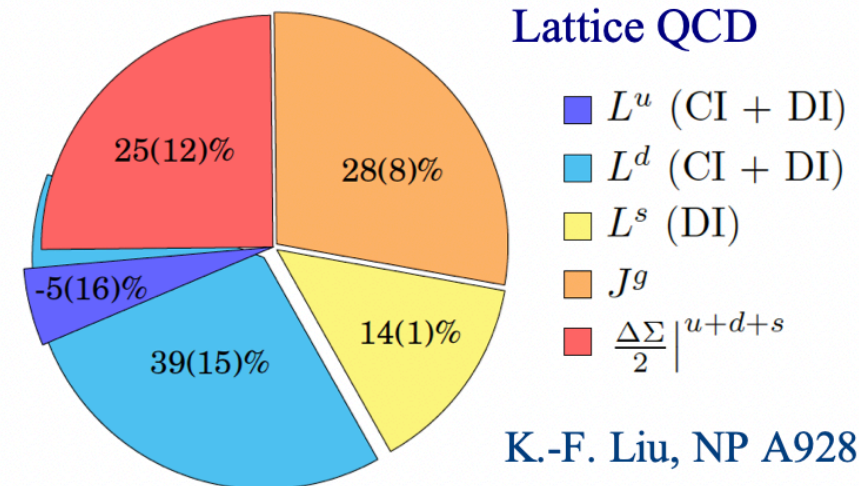


Gluon helicity

$$J = \frac{1}{2} \Delta\Sigma \overset{\sim 30\%}{+} \overset{\sim 10-20\%}{\Delta G} + \boxed{L_q + L_g} \overset{?}{+} \overset{?}{L_g}$$



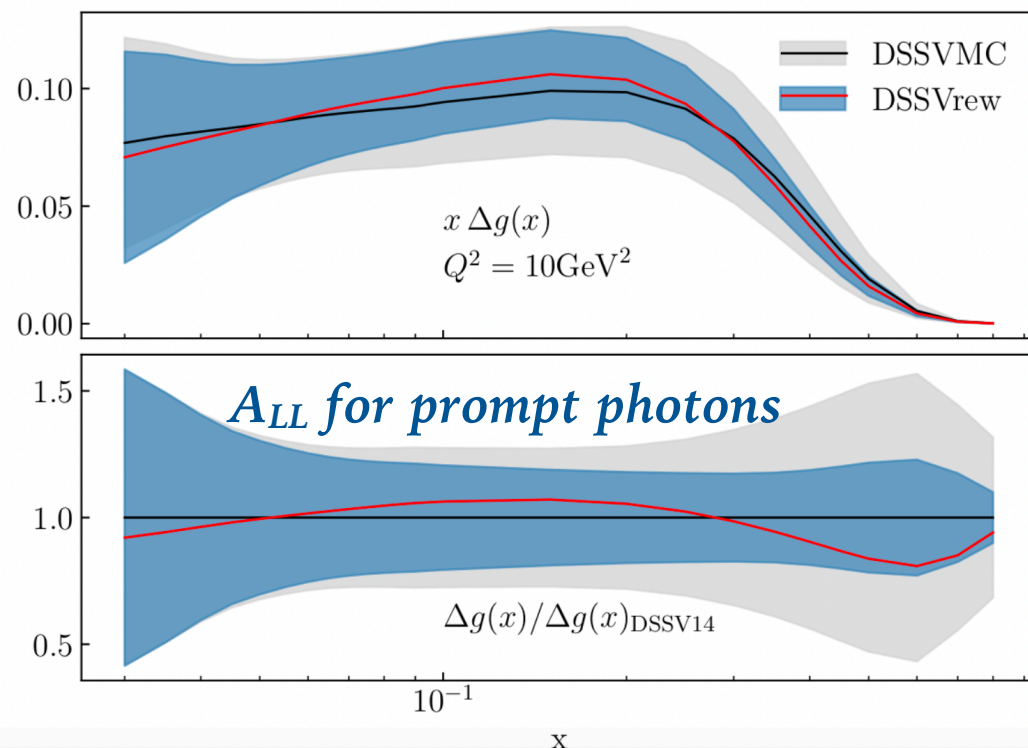
JAM Collaboration, PRD (2016).



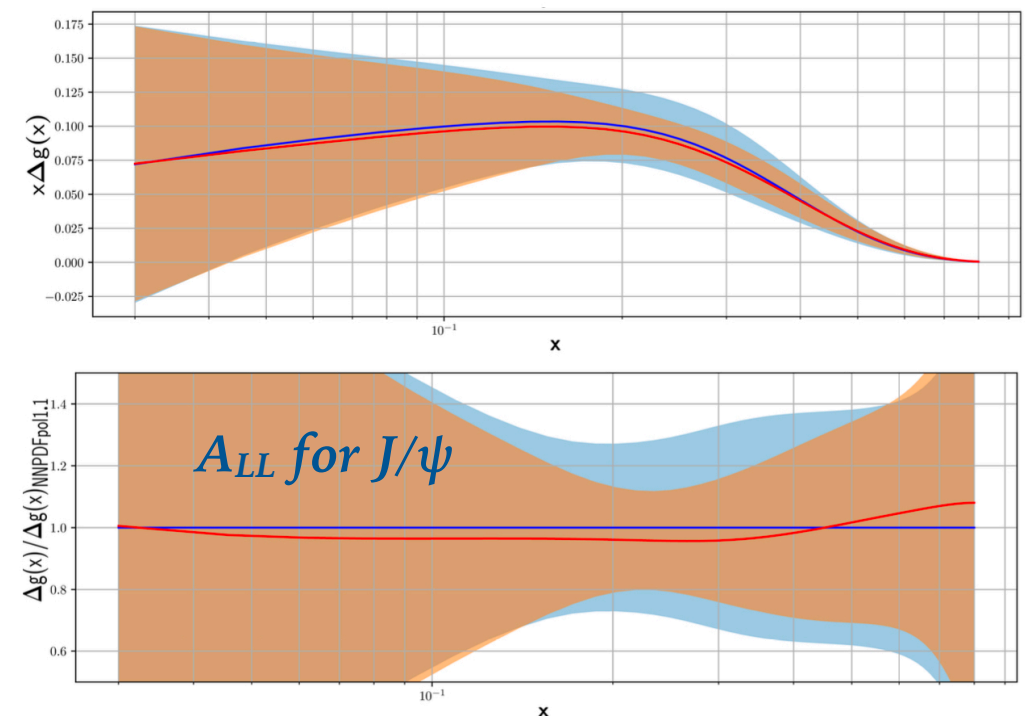
Lattice QCD

K.-F. Liu, NP A928, 99 (2014).

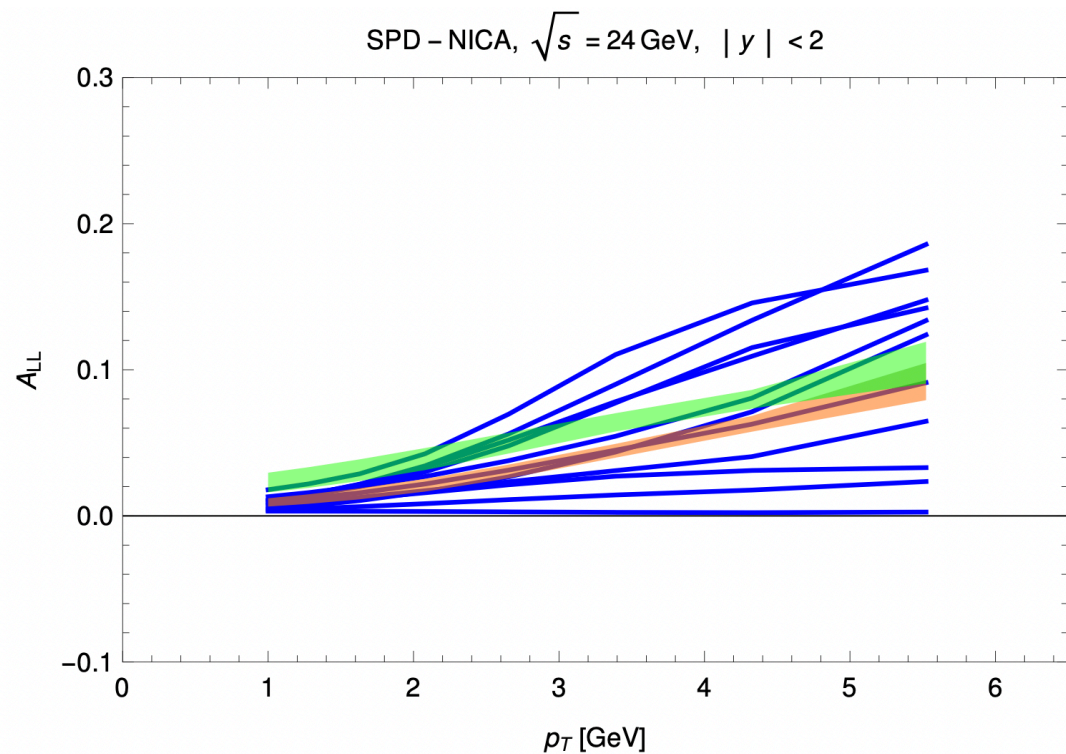
SPD impact (1 year at 27 GeV)



Vogelsang,
Sassot,
Borsa



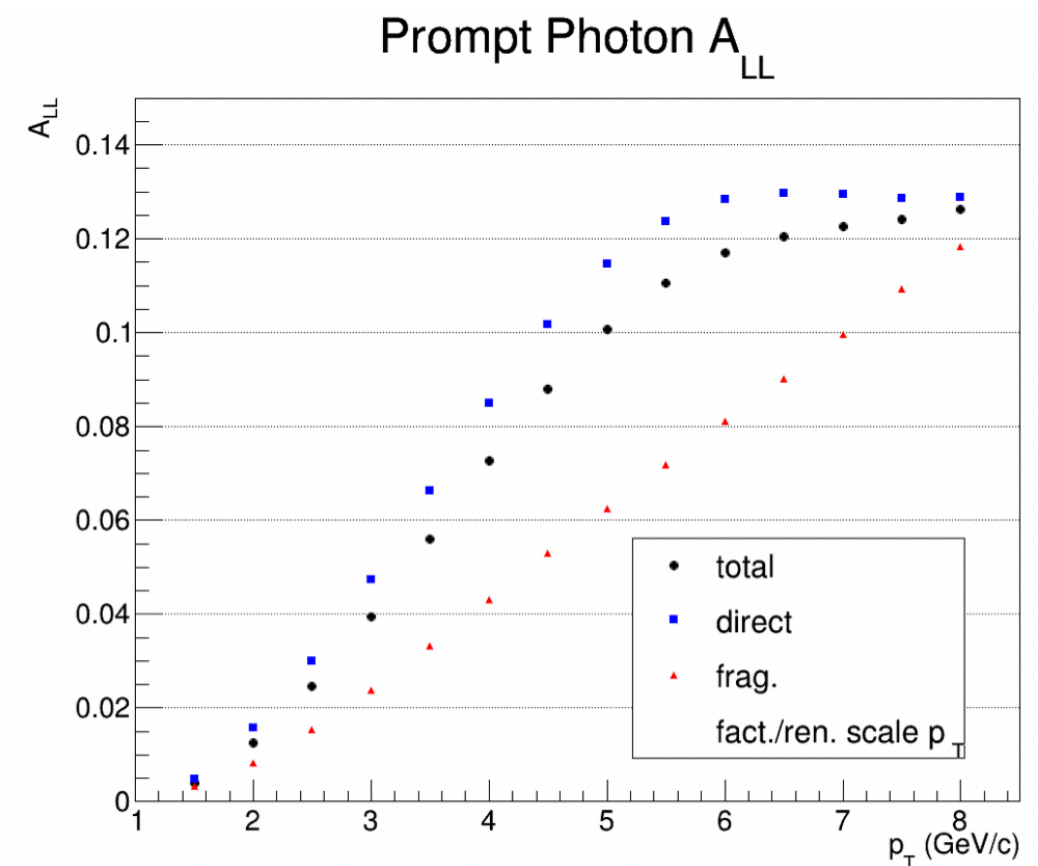
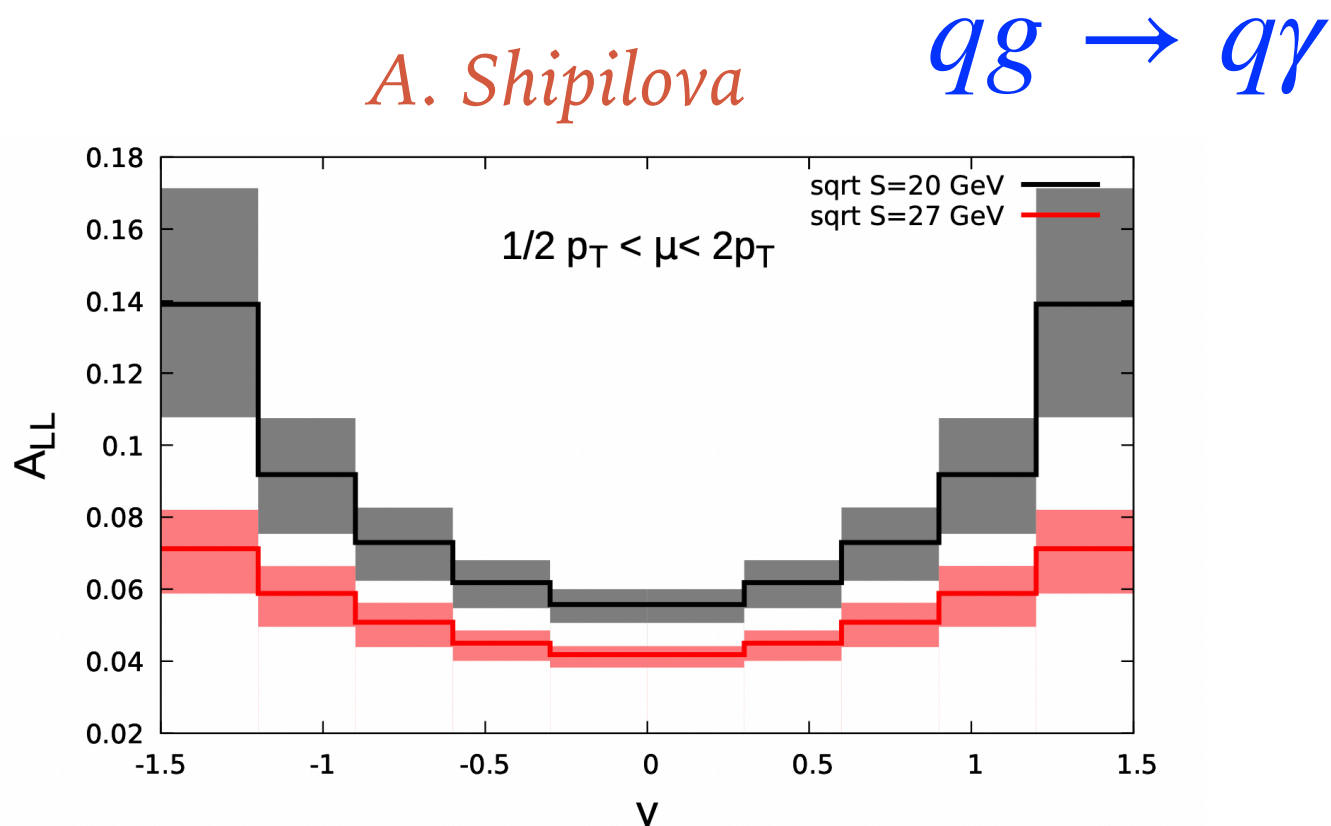
Gluon helicity function $\Delta g(x)$: expectations for A_{LL} at NICA energies



$gg \rightarrow J/\psi g$

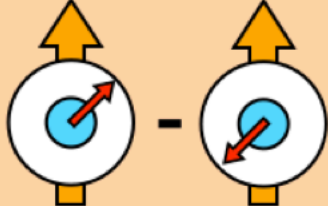
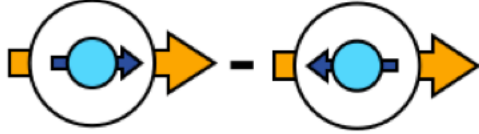
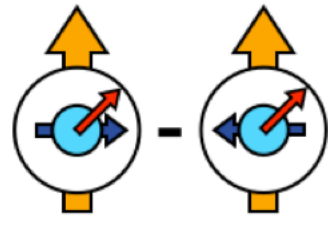
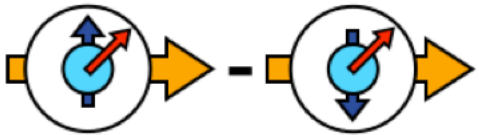
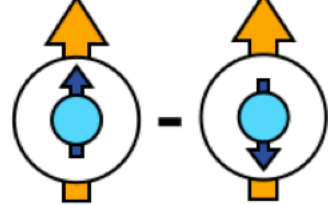
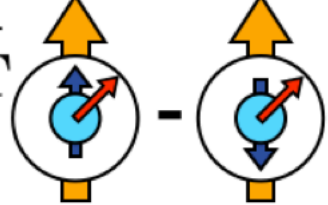
M. Nefedov

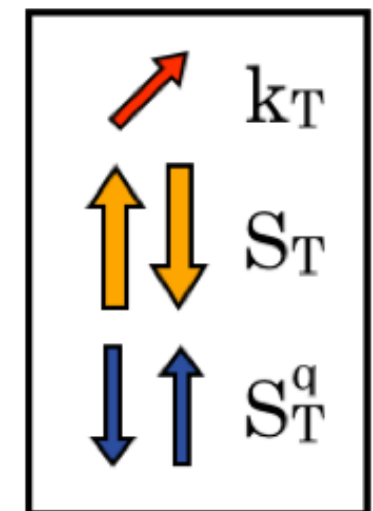
W. Vogelsang



Proton in 3D: TMD PDFs

Nucleon Spin Polarization

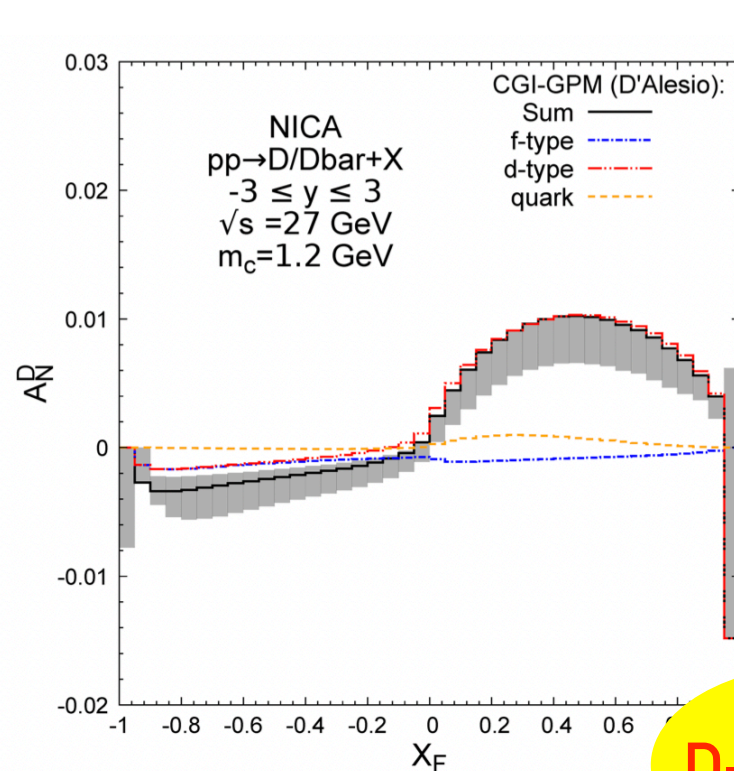
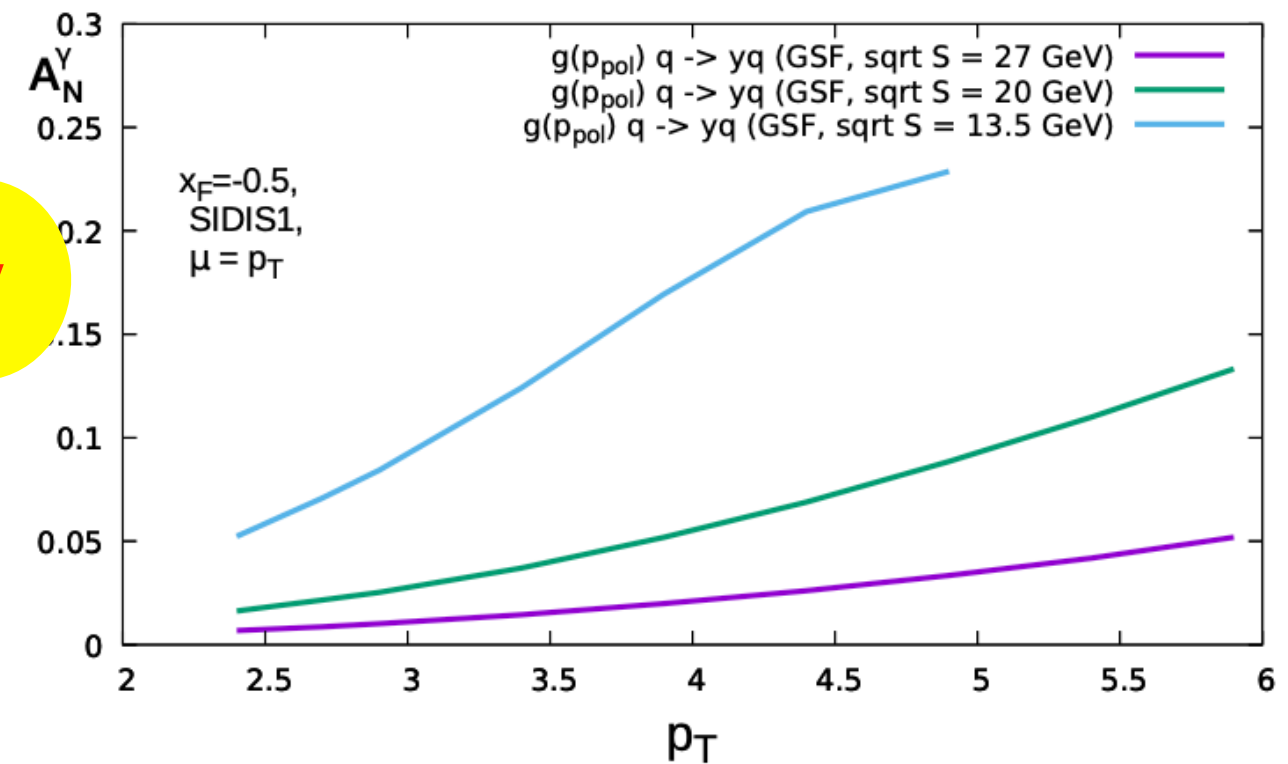
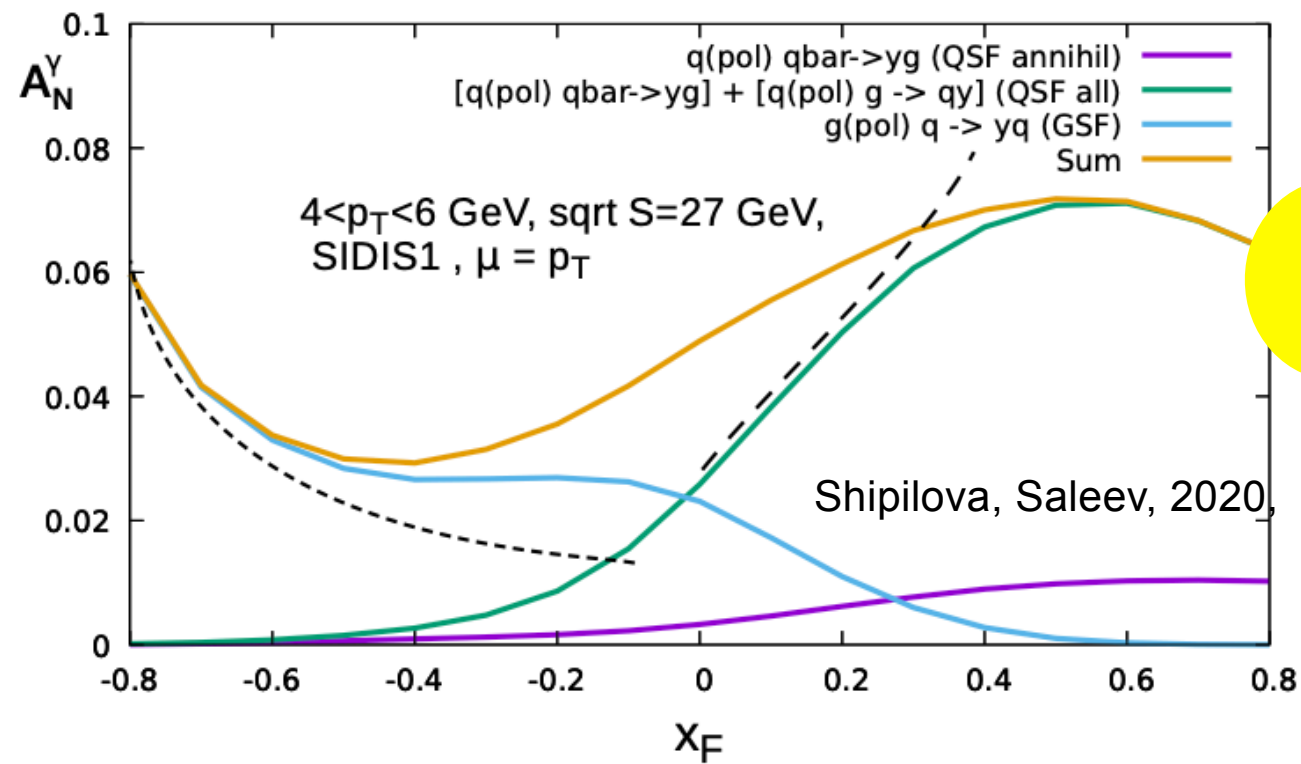
	U	L	T
U	f_1  Number Density		$f_1^{q\perp}$  Sivers
L		g_1^q  Helicity	g_1^q  Worm-Gear T
T	$h_1^{q\perp}$  Boer-Mulders	h_L^q  Worm-Gear L	h_1^q  Transversity $h_1^{q\perp}$  Pretzelosity



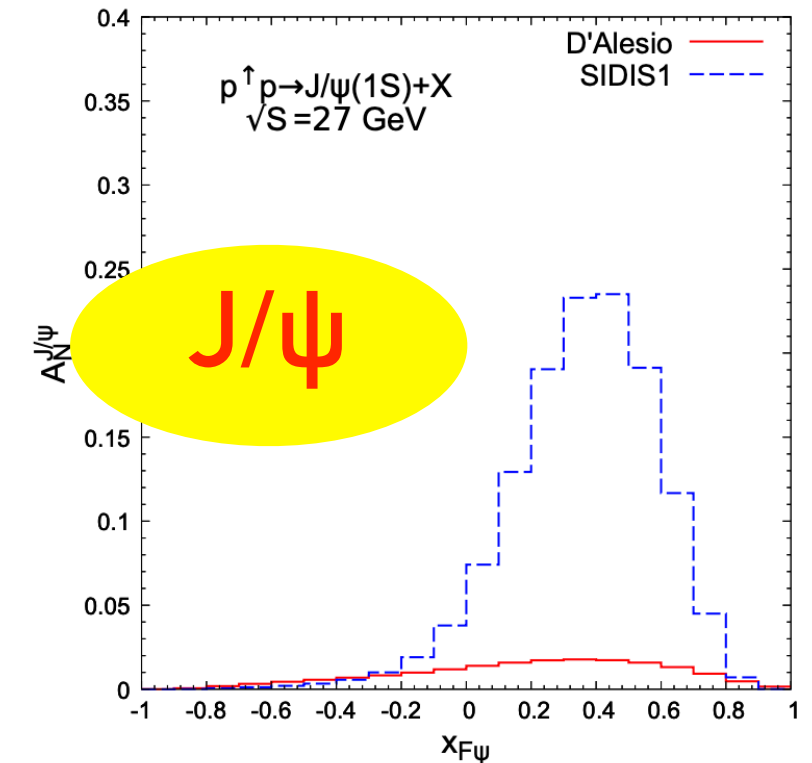
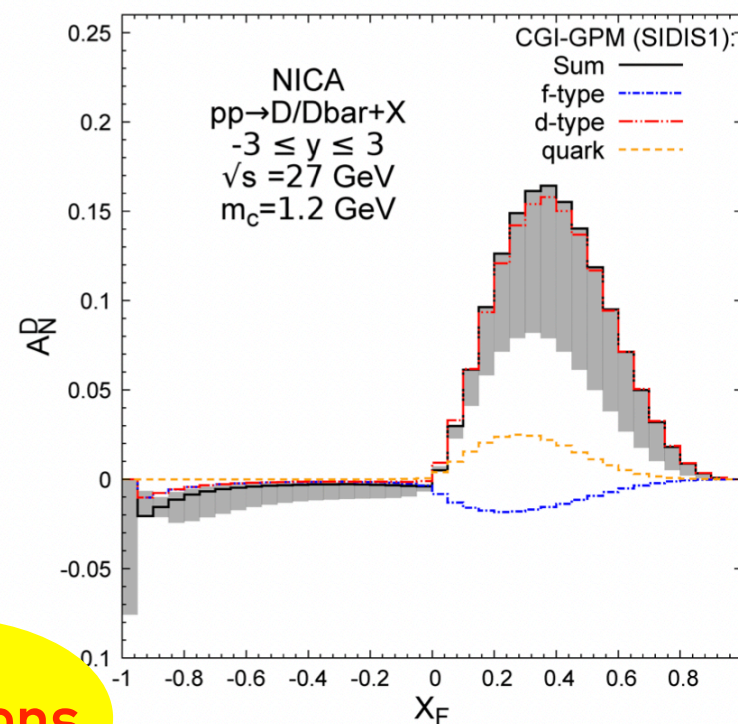
5 additional (TMD) functions describing the correlation between the nucleon spin, parton spin, and parton transverse momentum.

Gluon-induced TMD effects: expectations for A_N

Sivers effect contribution

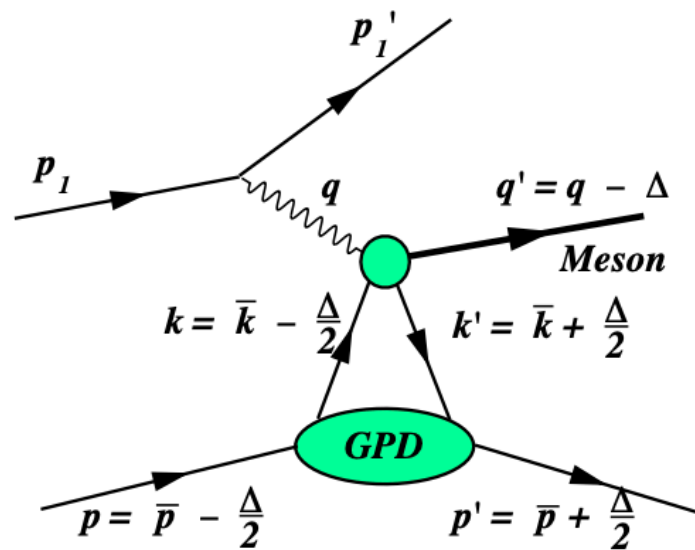


Saleev 2020

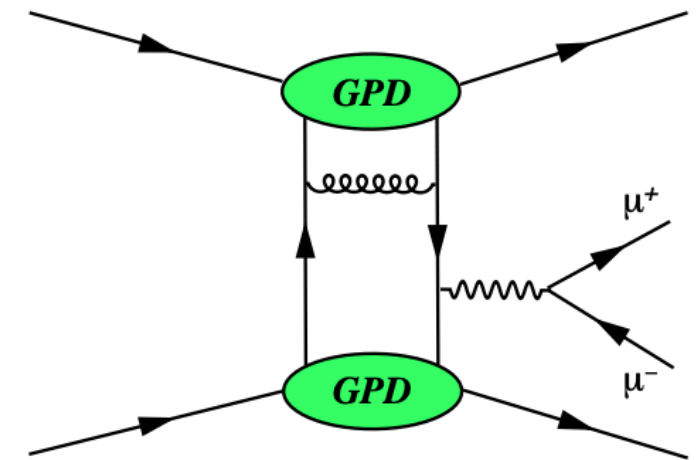
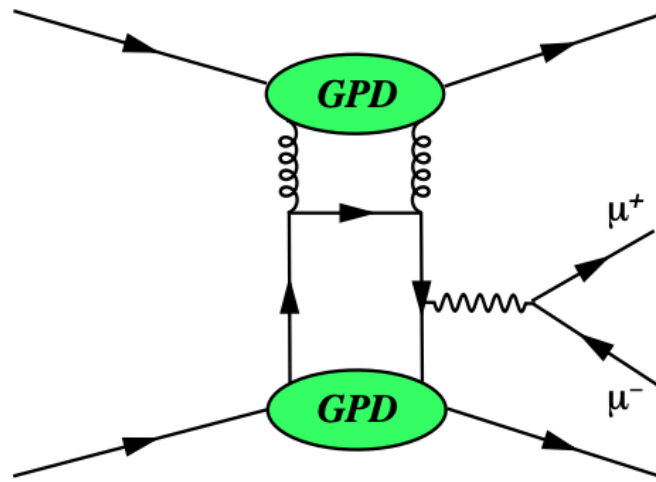


GPDs at SPD

GPDs is not a priority goal at SPD but potentially they could be accessed:

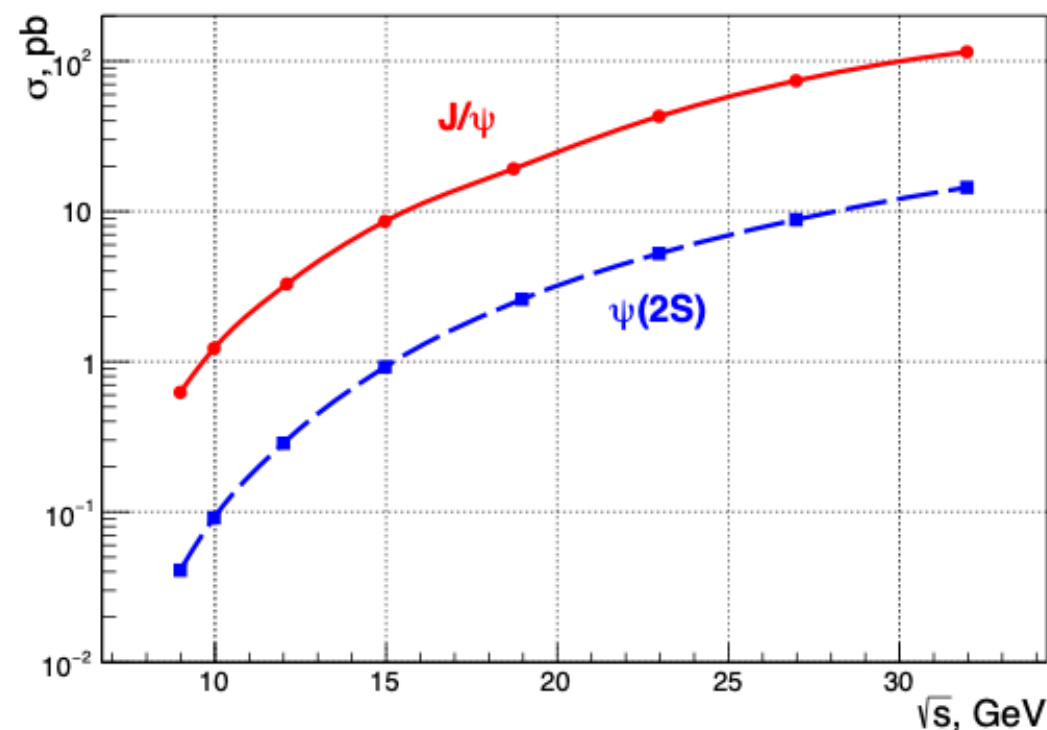


Exclusive Drell-Yan



$$d\sigma/dQ^2 \sim 5 \text{ pb}/(\text{GeV}/c)^2$$

at $\sqrt{s} = 24 \text{ GeV}$ and $Q^2 = 5 (\text{GeV}/c)^2$



Deuteron

$\sigma(x_F, p_T)$, vector and tensor angular asymmetries

Nonbaryonic content of deuteron:

$$|6q\rangle = c_1 |NN\rangle + c_2 |\Delta\Delta\rangle + c_3 |CC\rangle$$

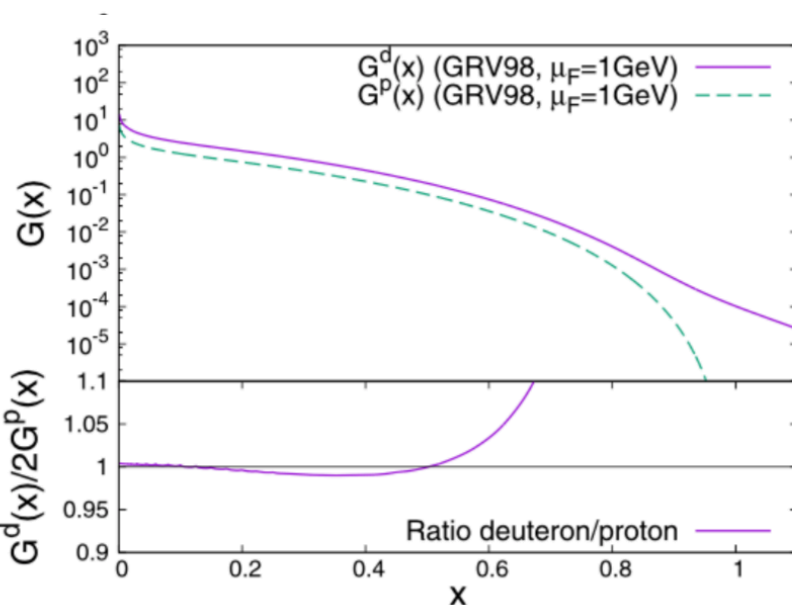
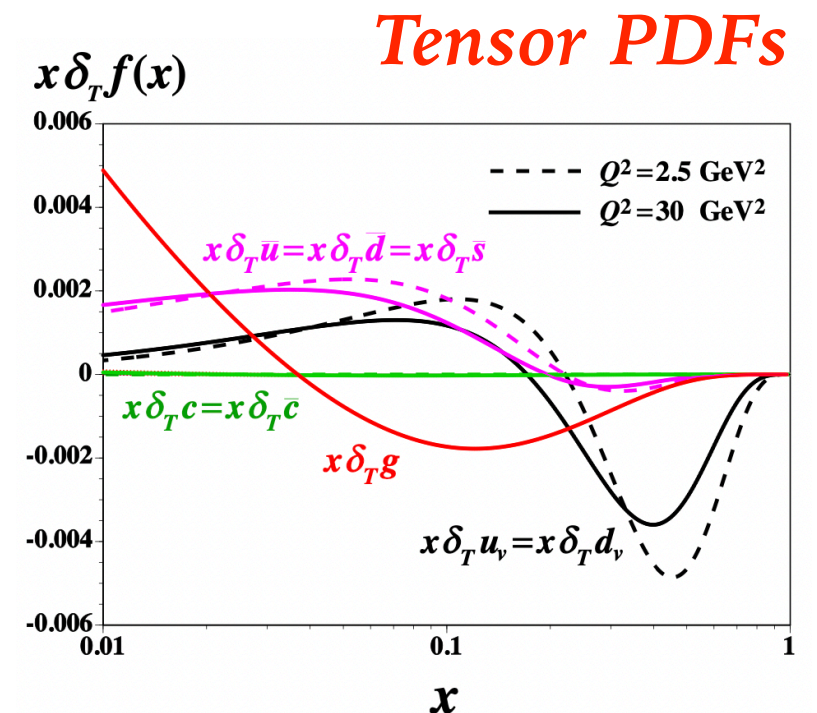
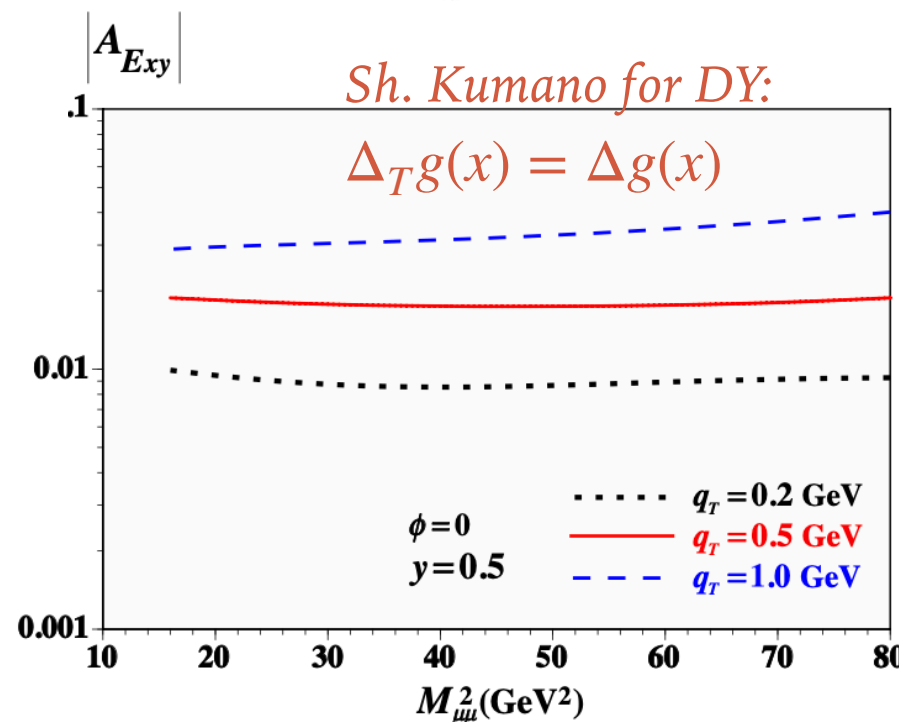
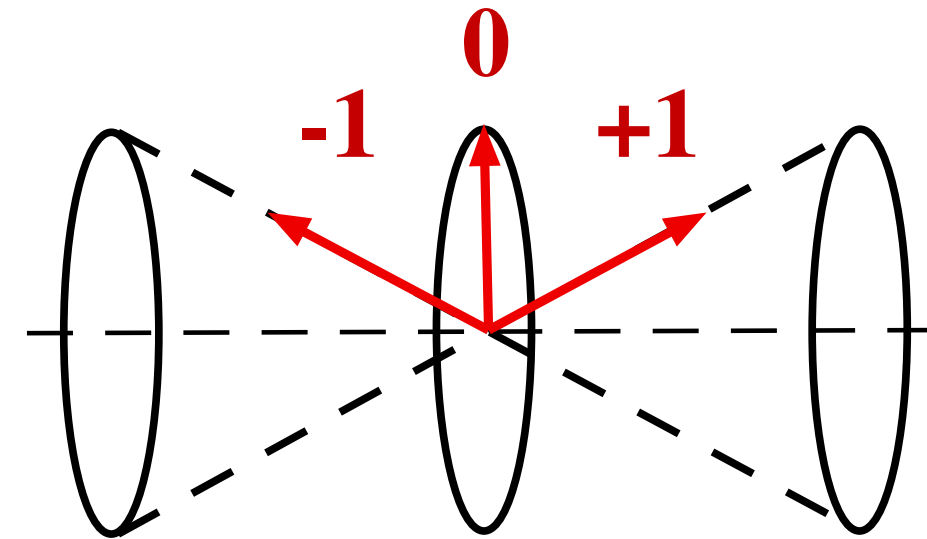
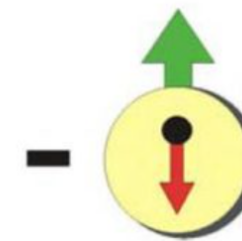
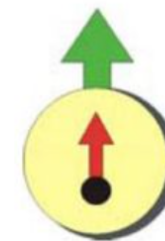
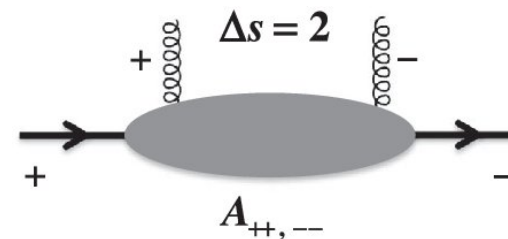


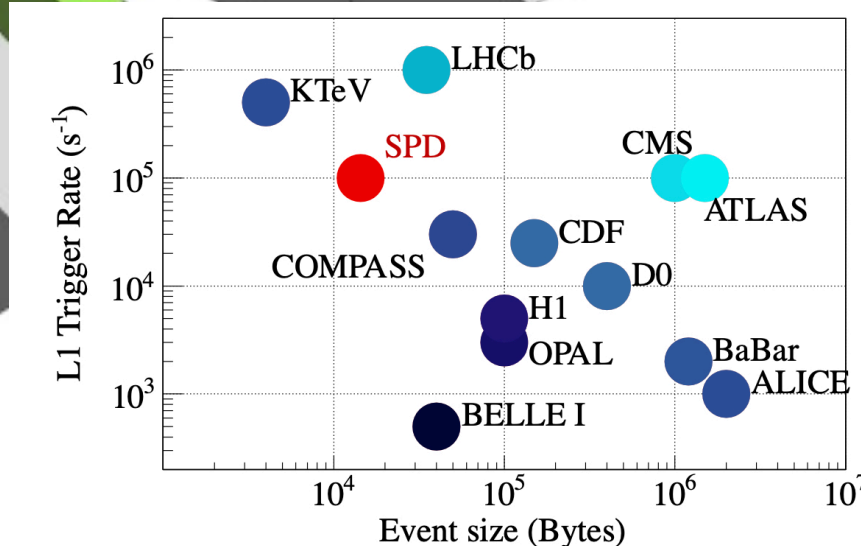
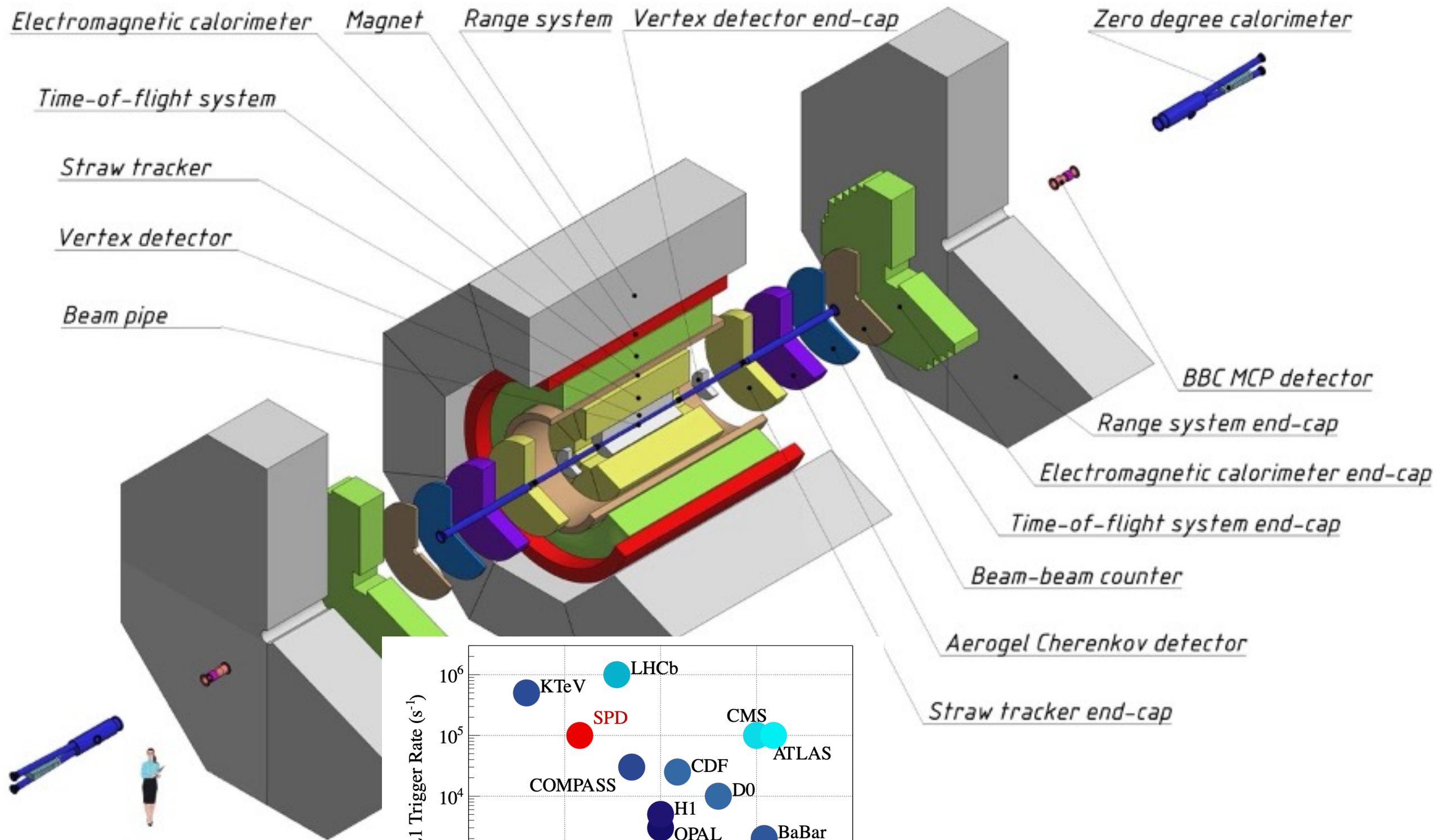
Fig. 6. Gluon PDF in the deuteron and in the nucleon.

Unpolarized
gluons at high x :

Gluon transversity



SPD setup



Free-running DAQ

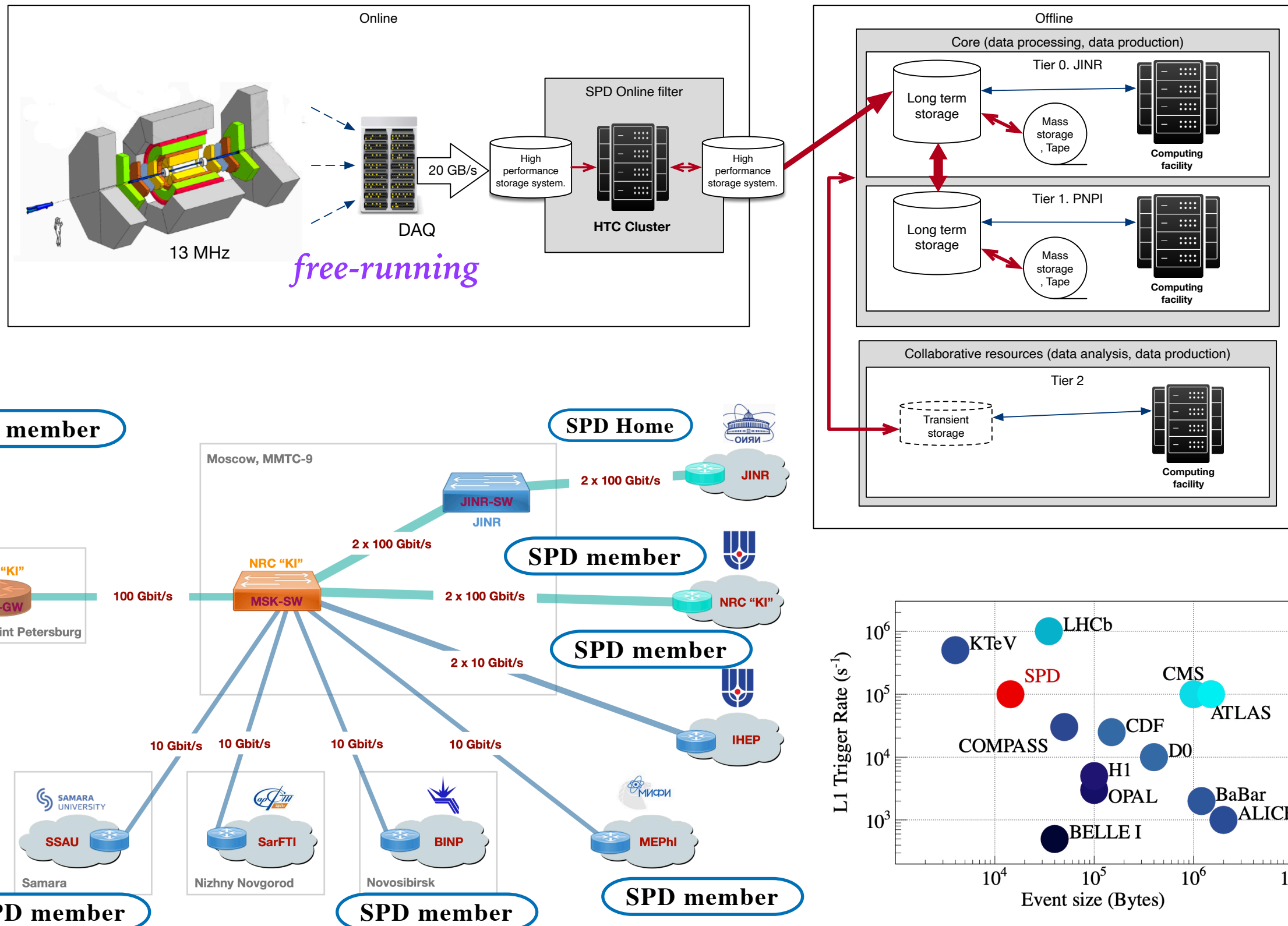
SPD setup: basic properties

	Stage I	Stage II
Maximum luminosity, $10^{32} \text{ cm}^{-2} \text{ s}^{-2}$	up to 0.1	1
Interaction rate, MHz	up to 0.4	4
Magnetic field at IP, T	up to 1.0	1.0
Track momentum resolution $\frac{\delta p}{p}$ at 1 GeV/c, %	~ 1.7	~ 1.0
Photon energy resolution, %		$5/\sqrt{E} \oplus 1$
$D^0 \rightarrow K\pi$ vertex spatial resolution, μm		60 for MAPS 80 for DSSD
PID capabilities	dE/dx , RS	dE/dx , ECal, RS, TOF, FARICH
Number of channels, 10^3	170 210	294 for MAPS) 397 for DSSD
Raw data flow, GB/s	up to 1	up to 20
Total weight, t	1236*	1240
Power consumption, kW	77	113 for MAPS 90 for DSSD

Detector	Spatial resolution	Time resolution	Energy resolution	Signal length
RS	3 mm (wires), 1 cm (strips)	150 ns	$90\%/\sqrt{E}$ (p, n)	250÷500 ns
ECal	5 mm (γ , 1 GeV)	1 ns	$5\%/\sqrt{E} \oplus 1\%$	
TOF	10 cm	50 ps	—	
FARICH		<1 ns	$d\beta/\beta < 10^{-3}$	10 ns
Straw	150 μm	1 ns	$8.5\%(dE/dx)$	120 ns
SVD MAPS	5 μm	—	—	
SVD DSSD	27.4 μm (ϕ) 81.3 μm (z)	—	—	
MCT	150 μm	10 ns	—	~ 300 ns
BBC inner	1.5 mm	50 ps	—	
BBC outer	~ 10 cm	400 ps	—	
ZDC	~ 1 cm	150 ps at 0.4 GeV	$50\%/\sqrt{E} \oplus 30\%$ (n) $20\%/\sqrt{E} \oplus 9\%$ (γ)	

IT infrastructure

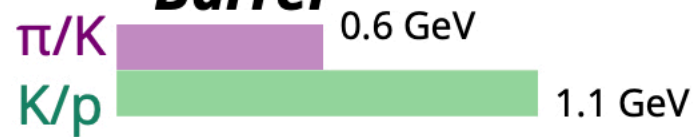
SPD data flow



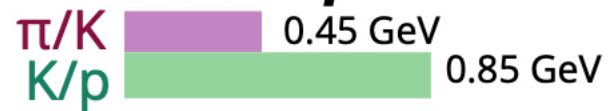
PID capabilities

Straw tracker

Barrel



End-Cap



TOF

Barrel

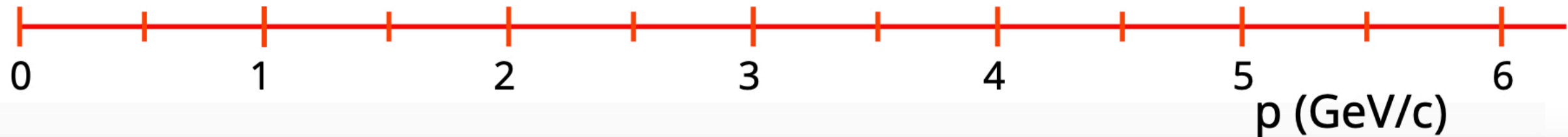


End-Cap



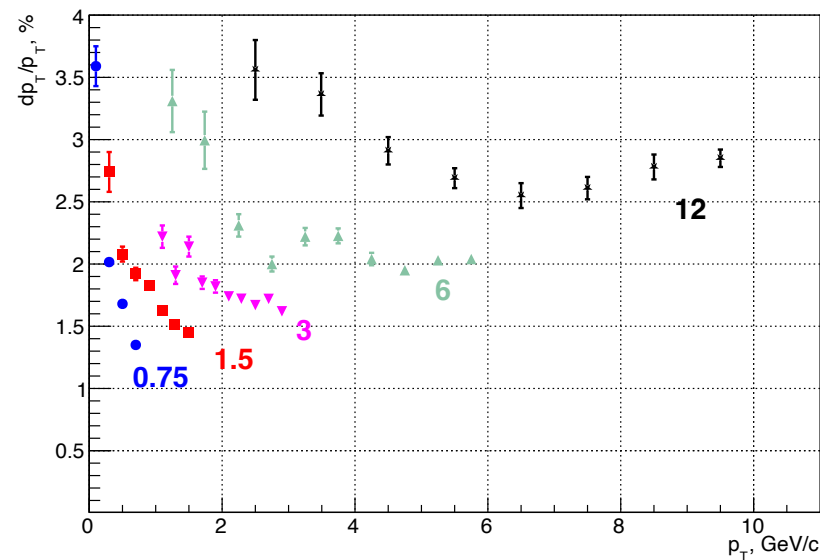
FARICH

End-Cap

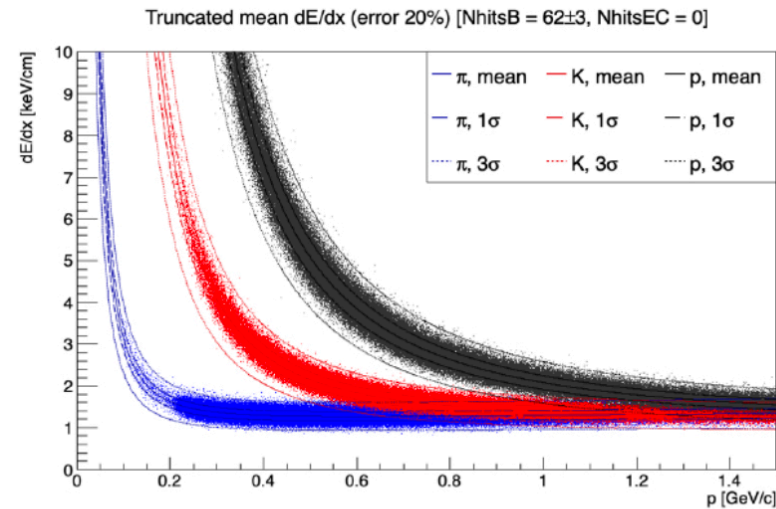


Detector performance

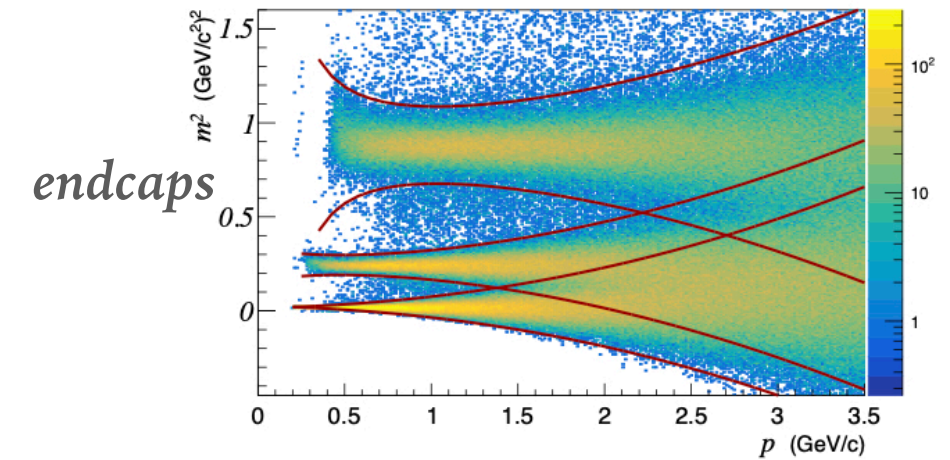
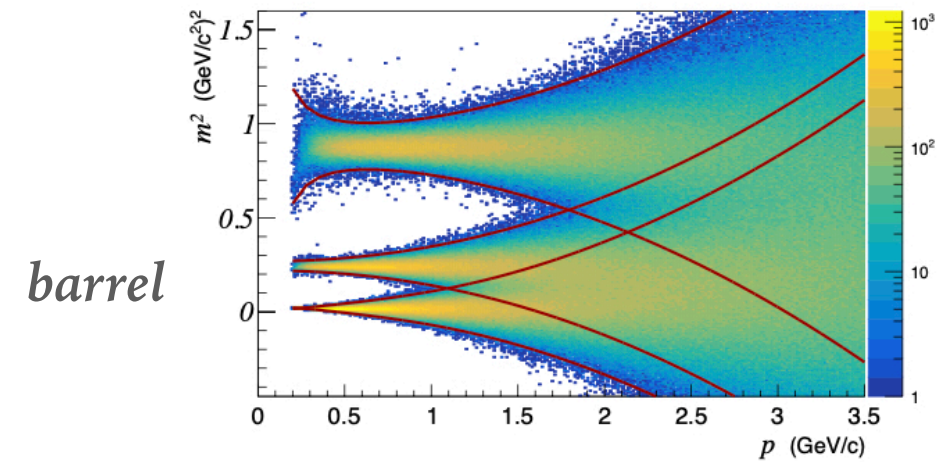
Momentum resolution



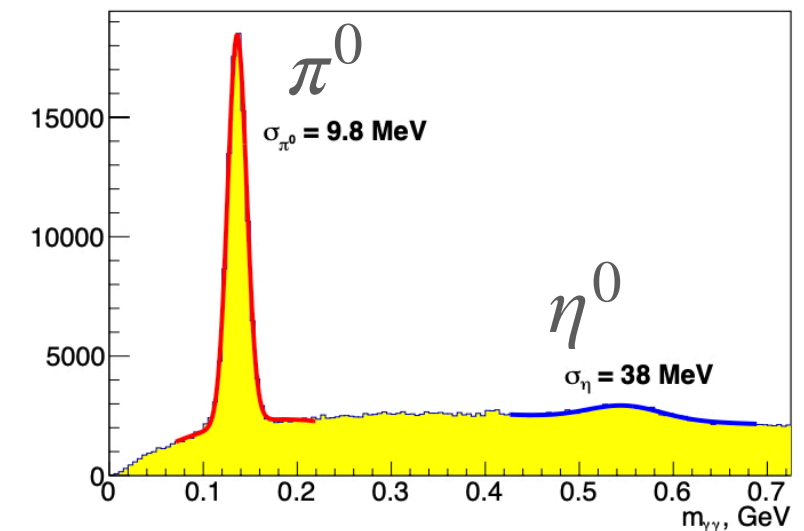
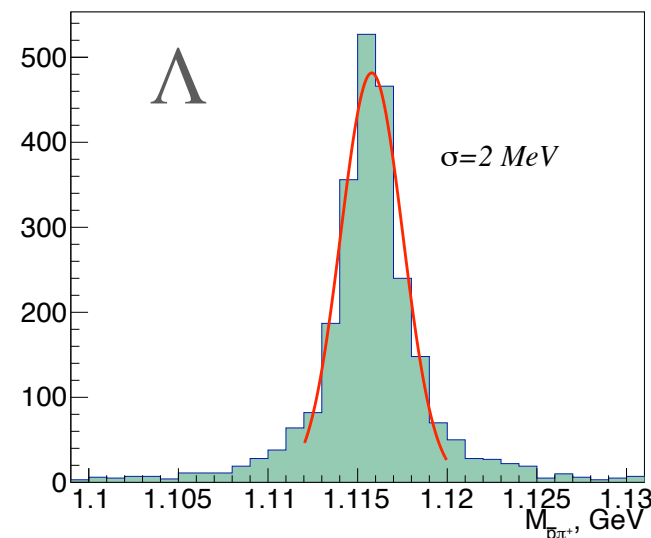
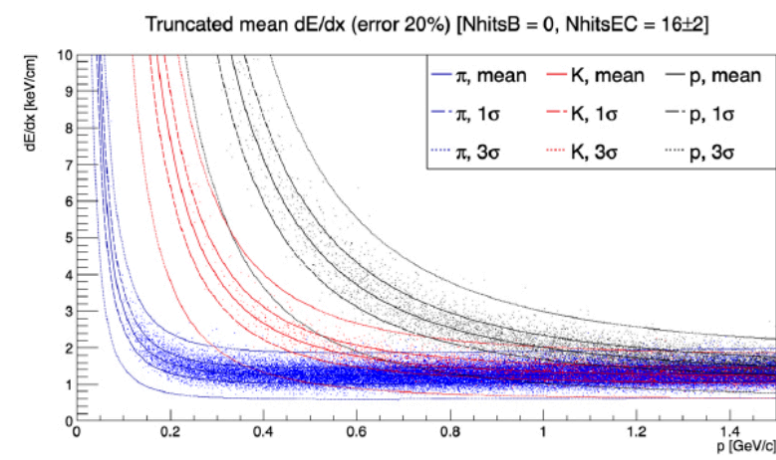
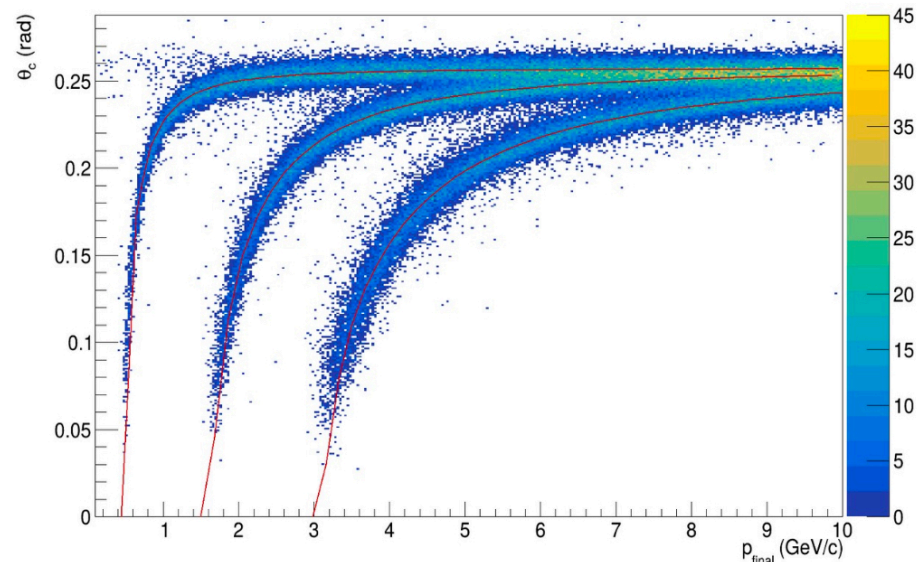
dE/dx in Straw tracker



TOF performance

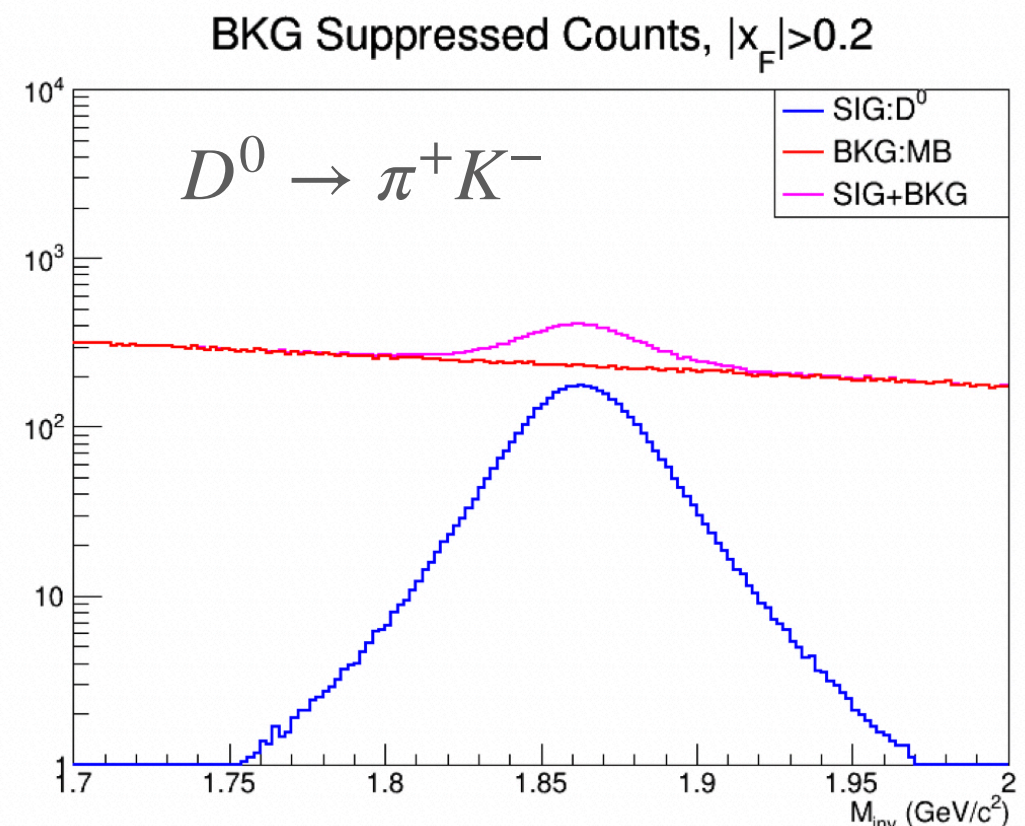
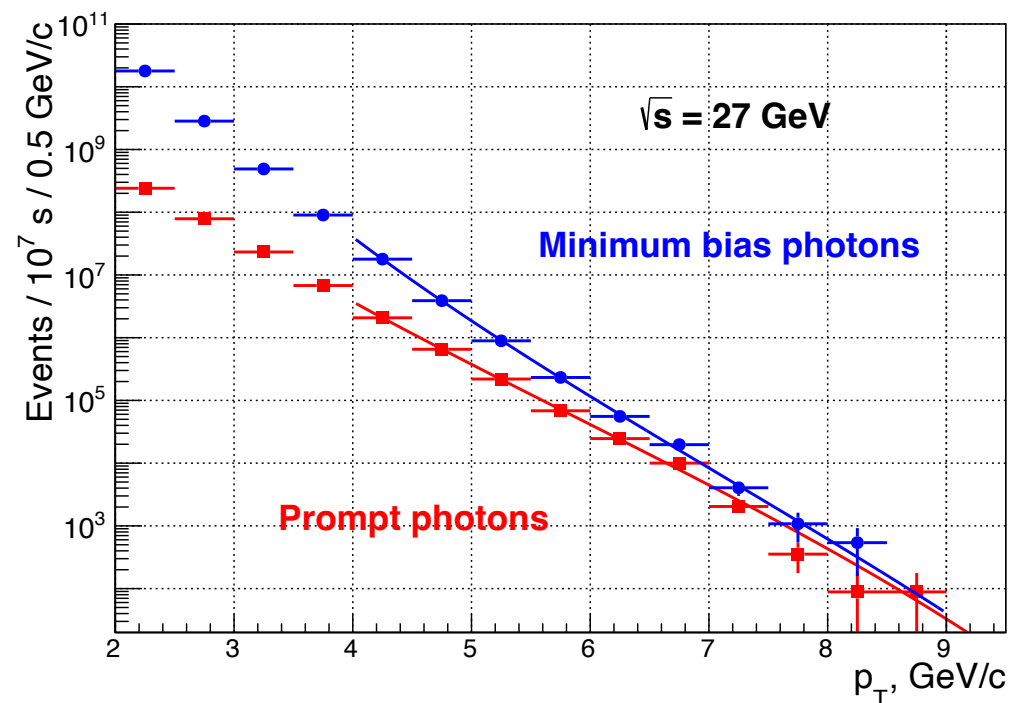
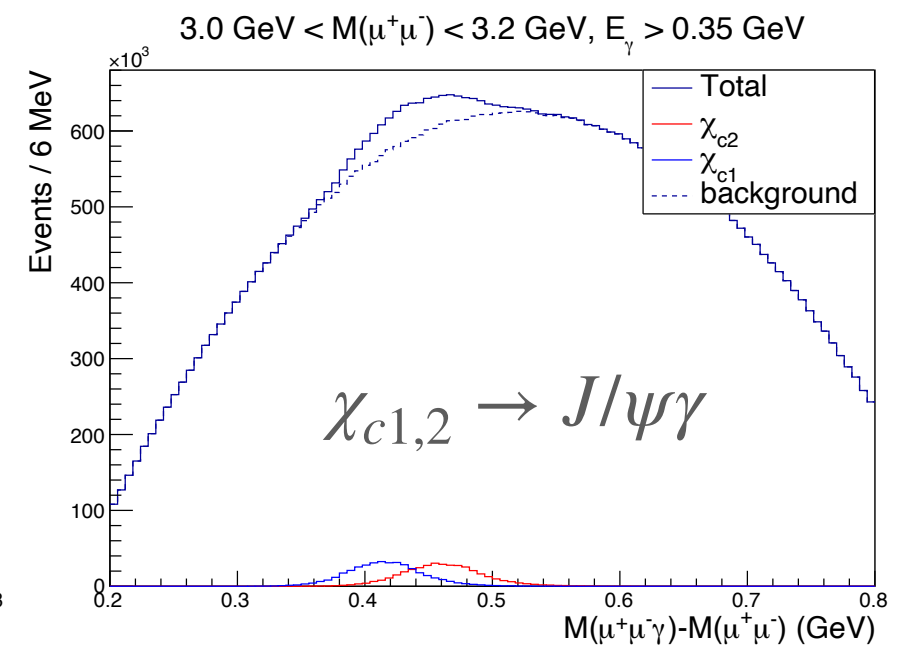
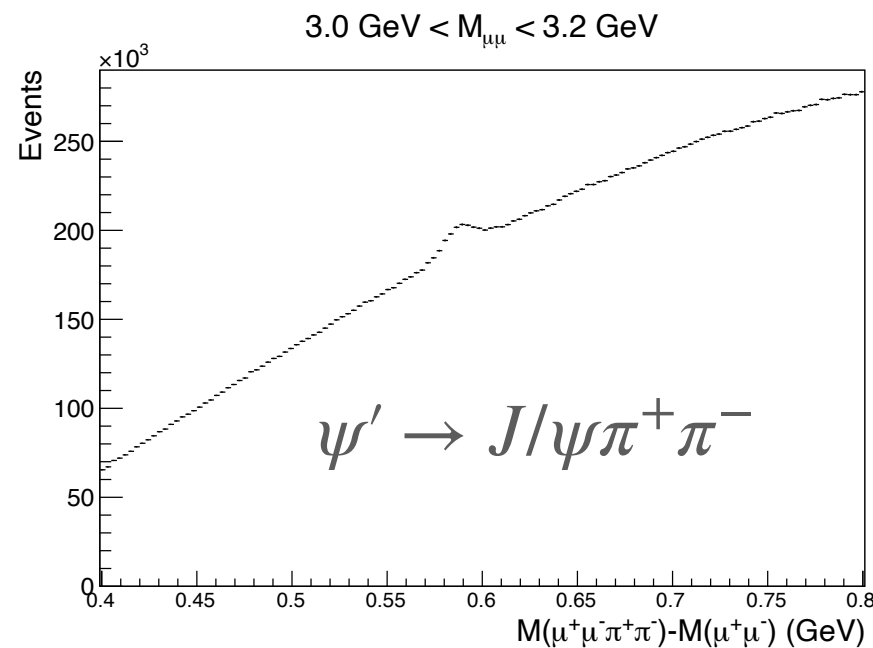
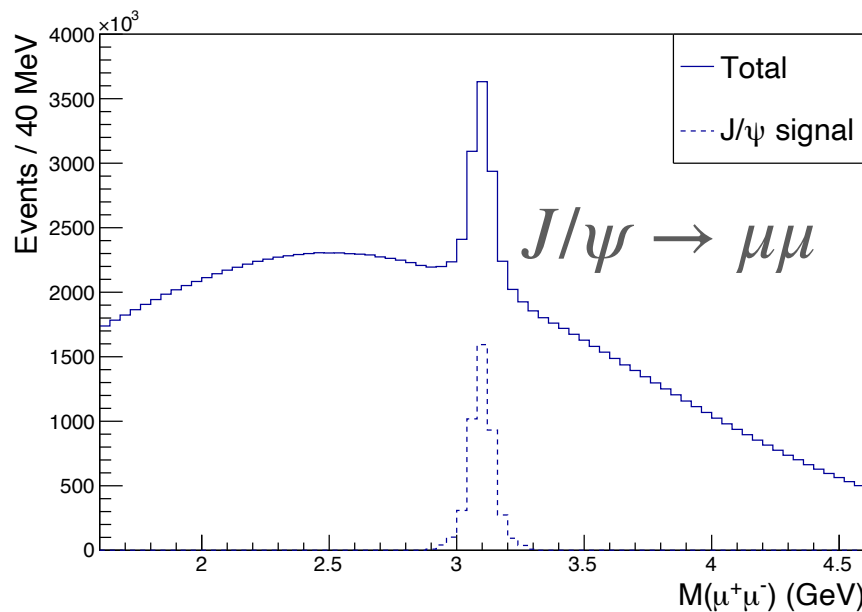


FARICH performance

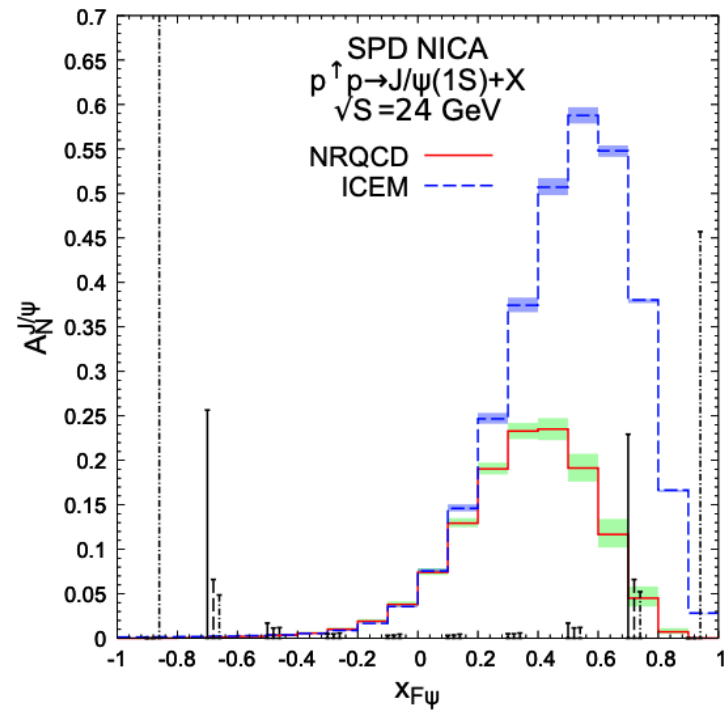


Physics performance: gluon probes

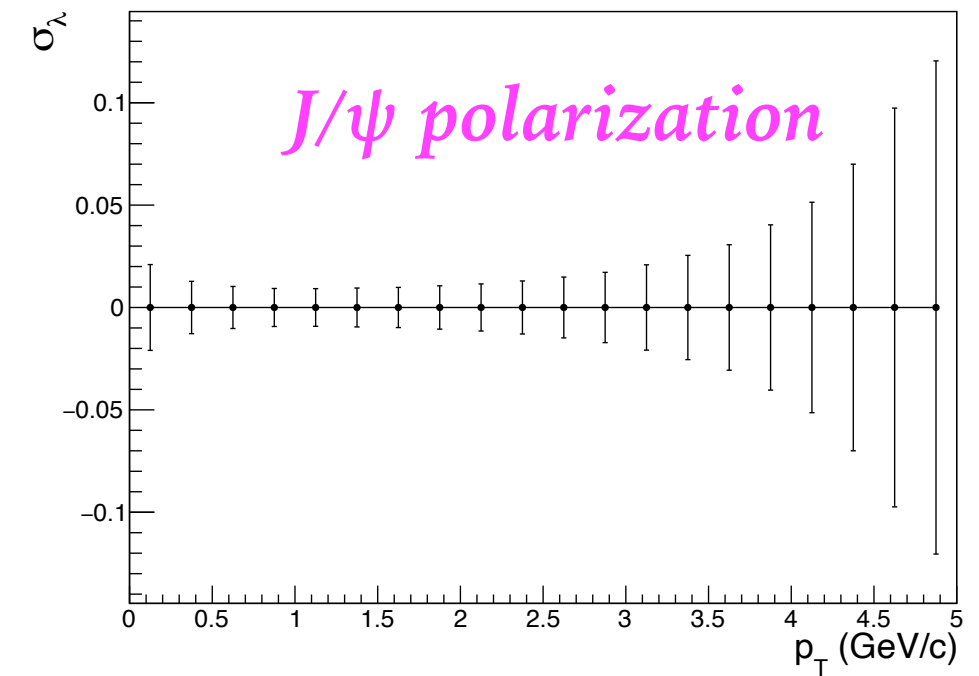
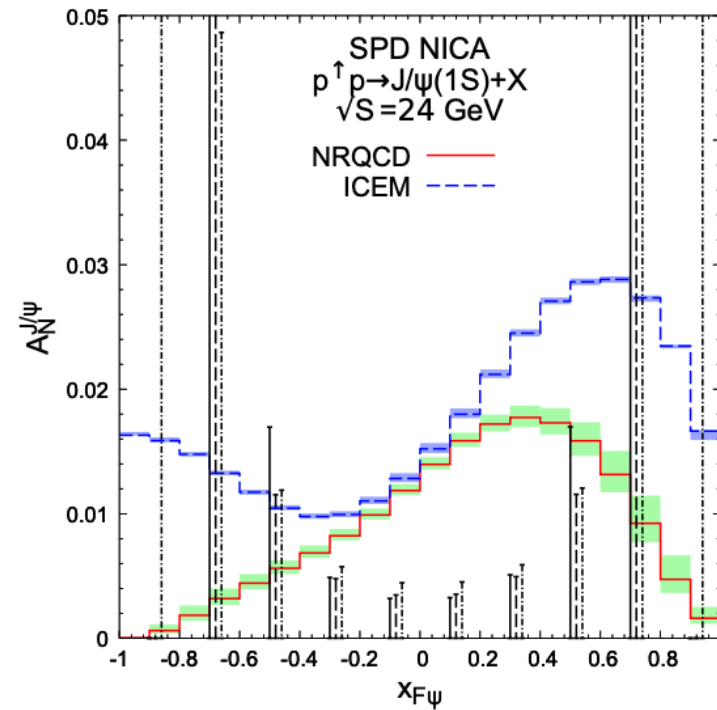
(1 year = 10^7 s, 27 GeV)



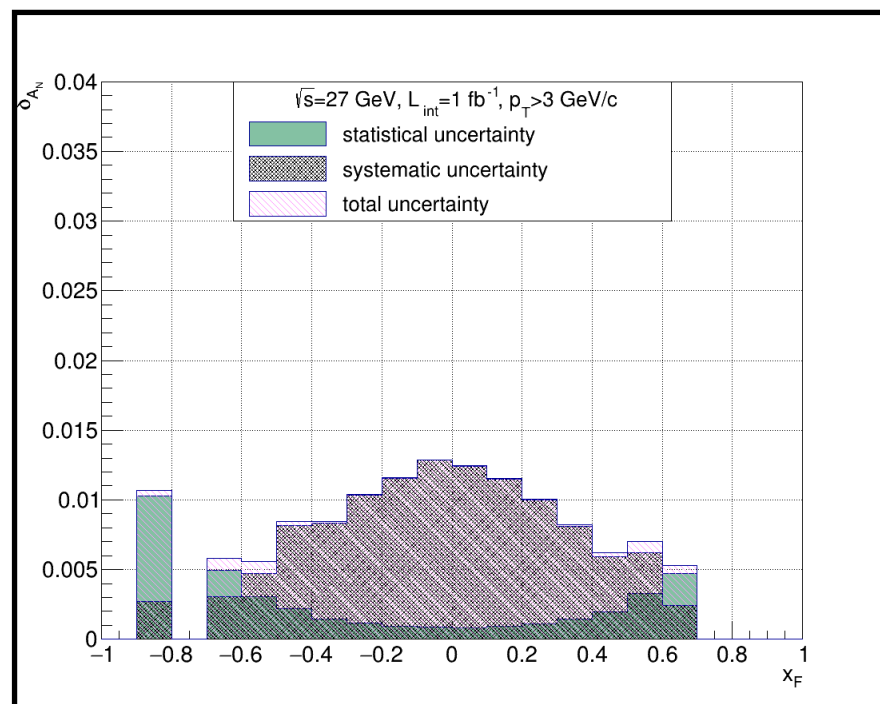
Physics performance: accuracies



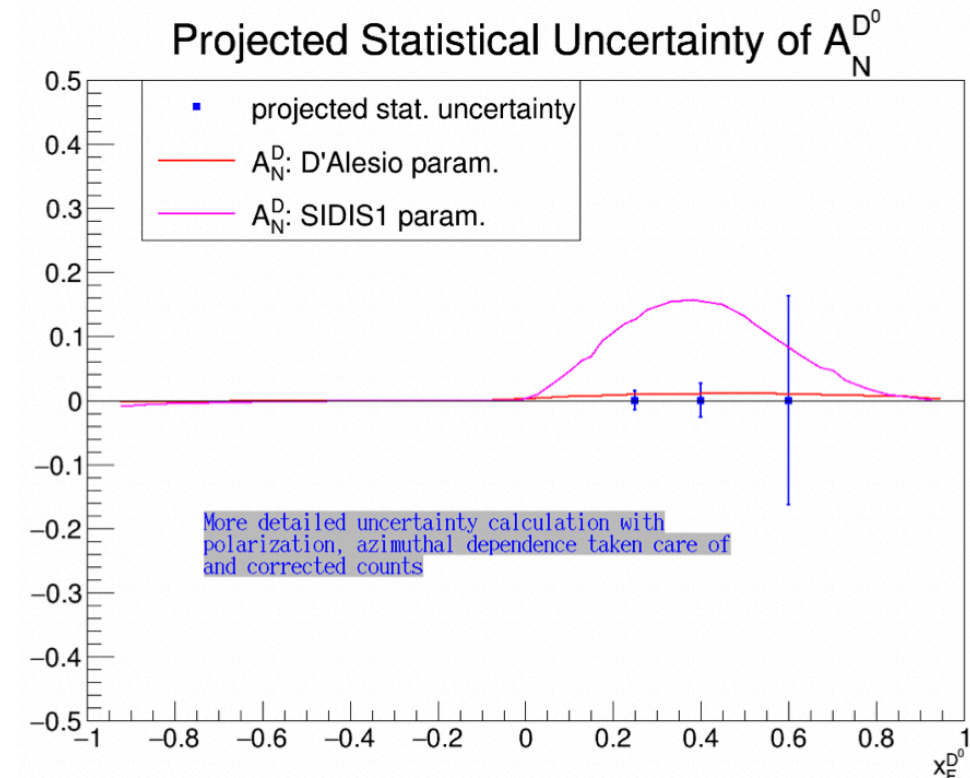
J/ψ



Different inputs for gluon Sivers function

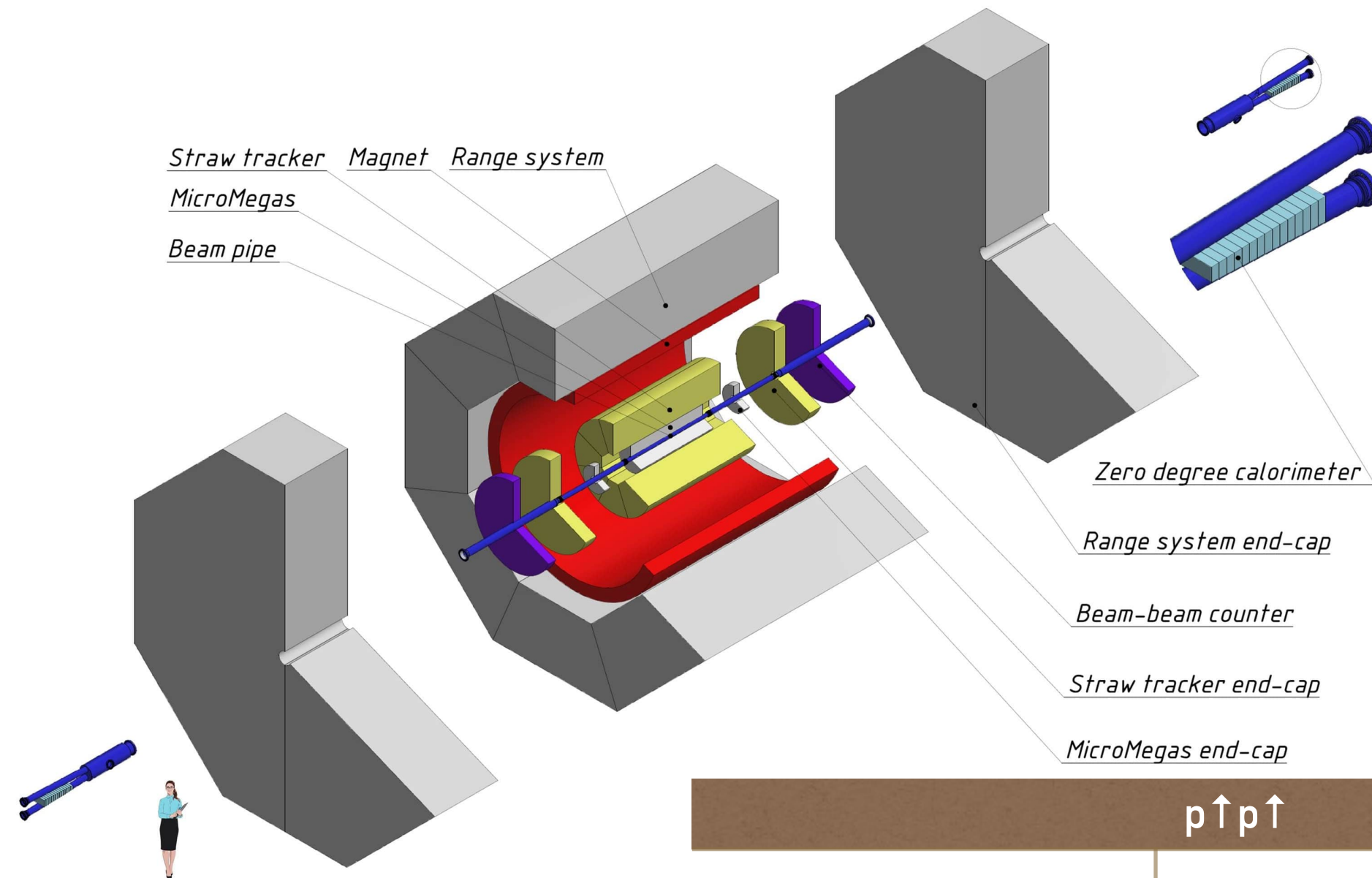


prompt-γ



D⁰

SPD setup: 1st phase



	p↑p↑	d↑d↑	AA
	First phase		
$\sqrt{s_{NN}}$, GeV	< 9.4	< 4.5	< 4.5
L, $10^{30} \text{ cm}^{-1} \text{ s}^{-1}$	< 10	< 1	< 0.001
	Second phase		
$\sqrt{s_{NN}}$, GeV	< 27	< 13.5	
L, $10^{30} \text{ cm}^{-1} \text{ s}^{-1}$	< 100	< 10	

First-phase physics

arXiv:2102.08477

Phys.Part.Nucl. 52 (2021) 6, 1044-1119

Non-perturbative QCD

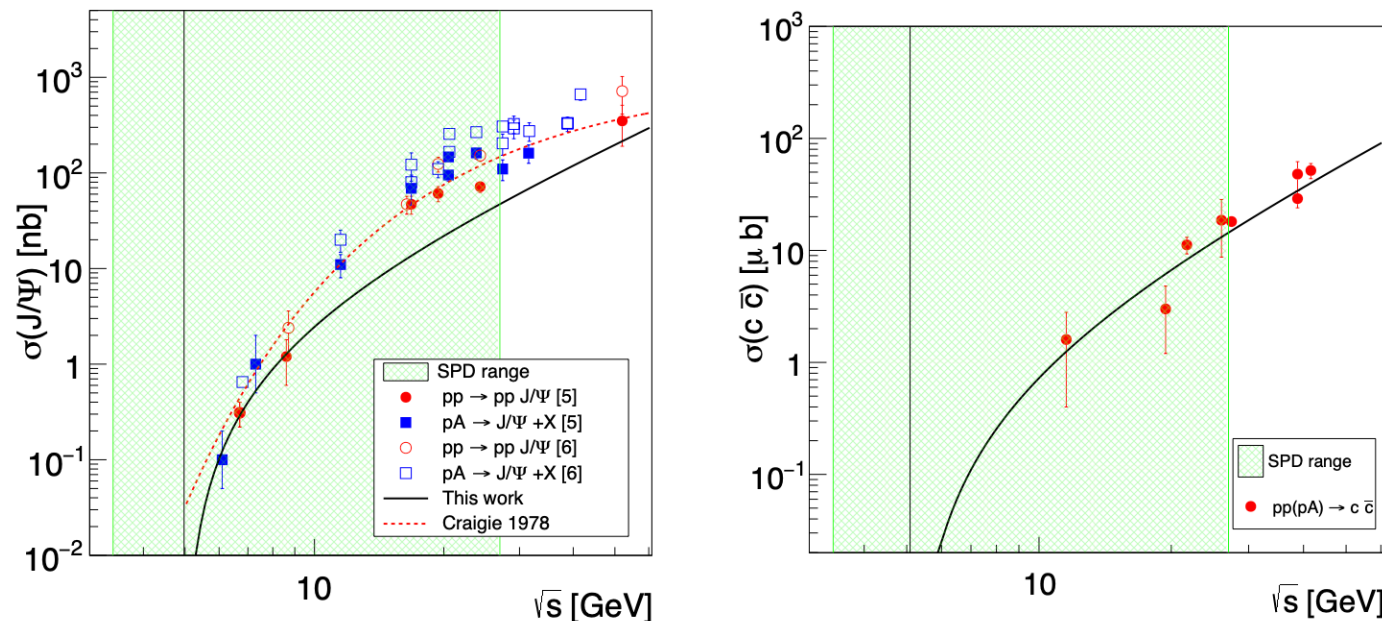
Perturbative QCD

- Spin effects in p-p, d-d elastic scattering
- Spin effects in hyperons production
- Multiquark correlations
- Dibaryon resonances
- Physics of light and intermediate nuclei collision
- Exclusive reactions
- Hypernuclei
- Open charm and charmonia near threshold

$$pp \rightarrow (6q)^* \rightarrow N N \text{ Mesons},$$

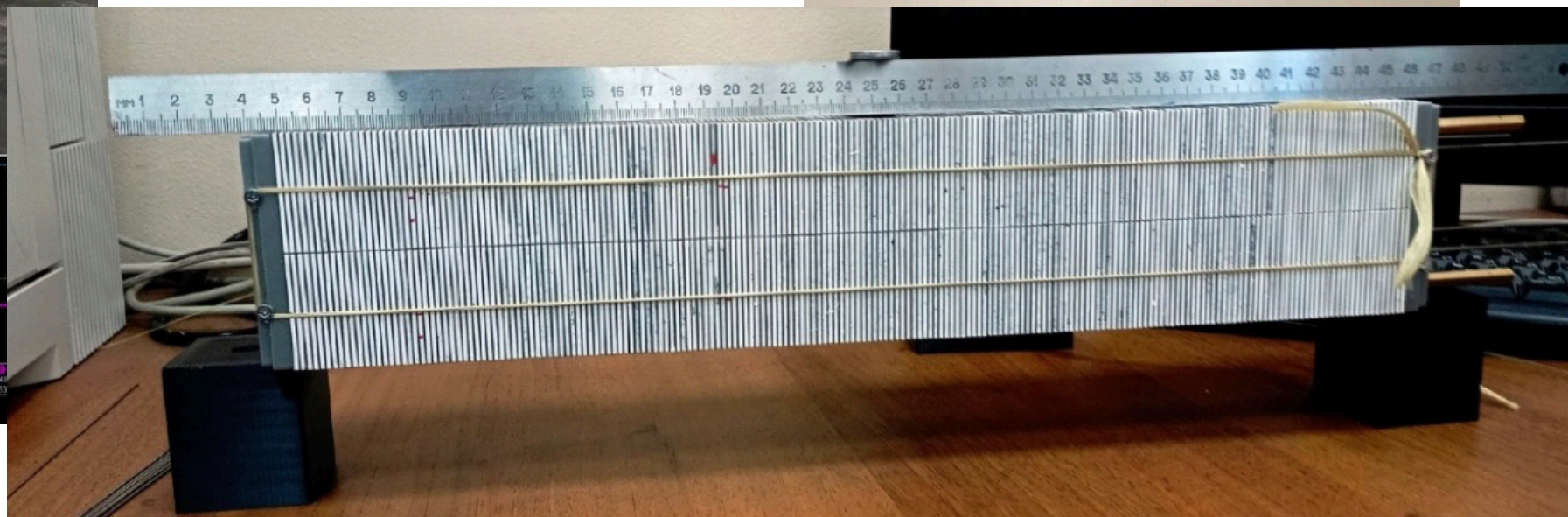
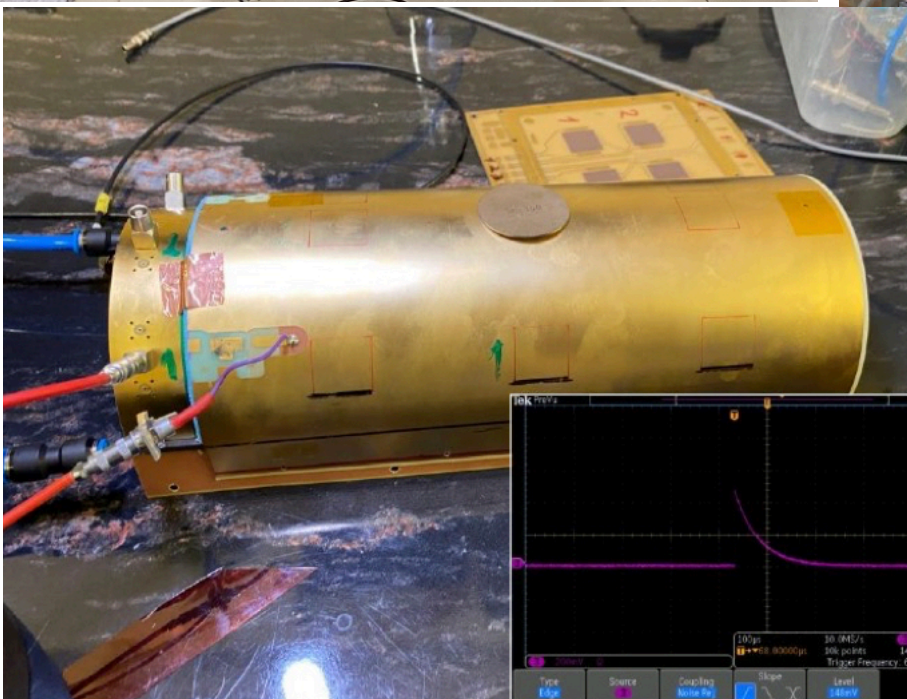
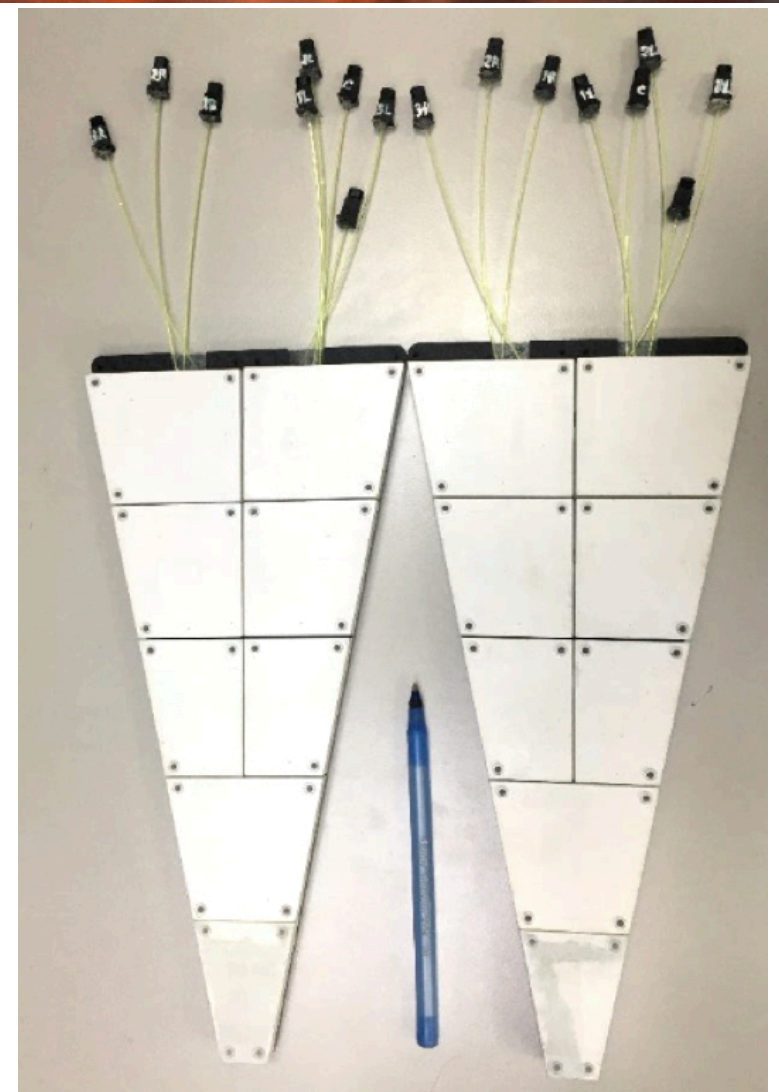
$$dd \rightarrow K^+ K^+ \Lambda\Lambda^4 n,$$

$\sqrt{s}$

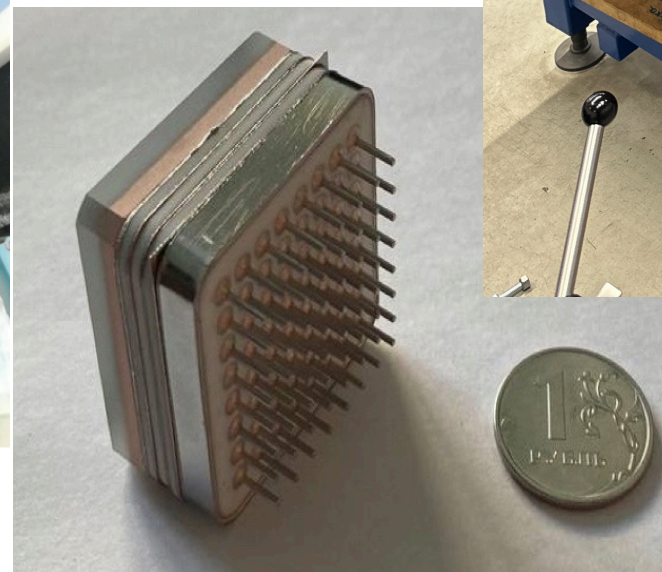
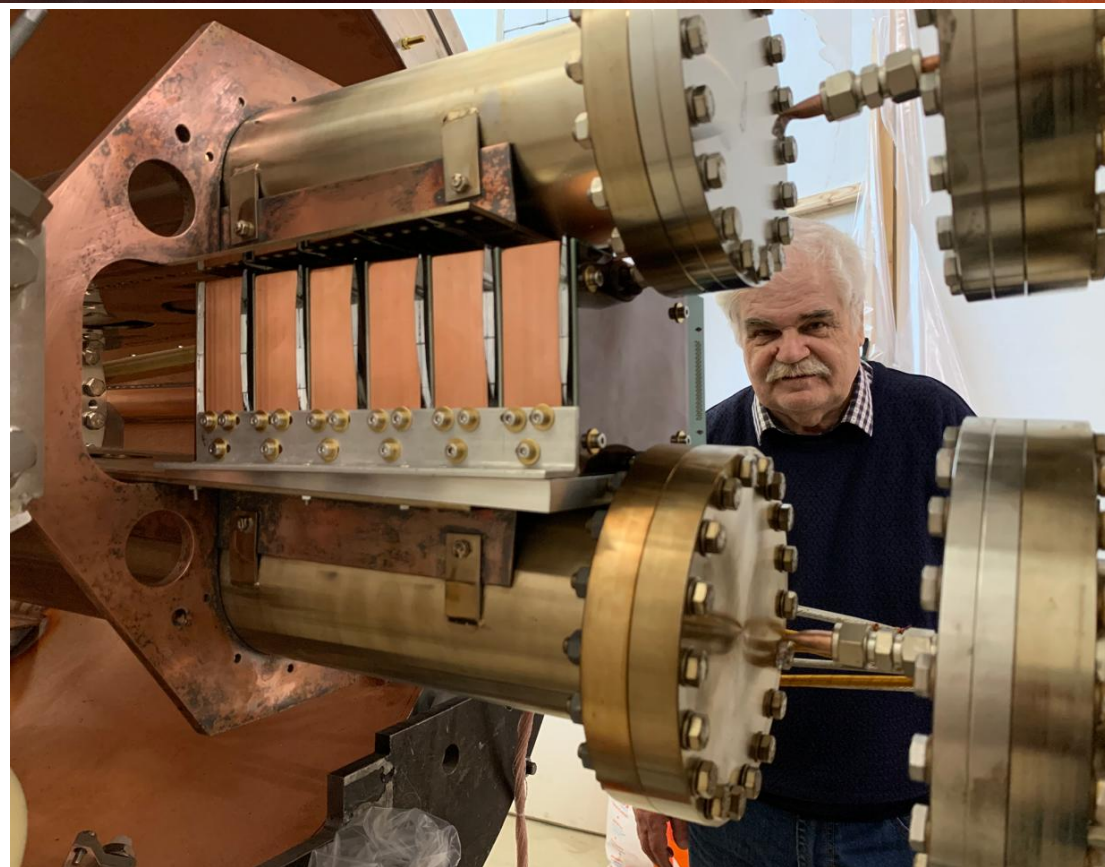
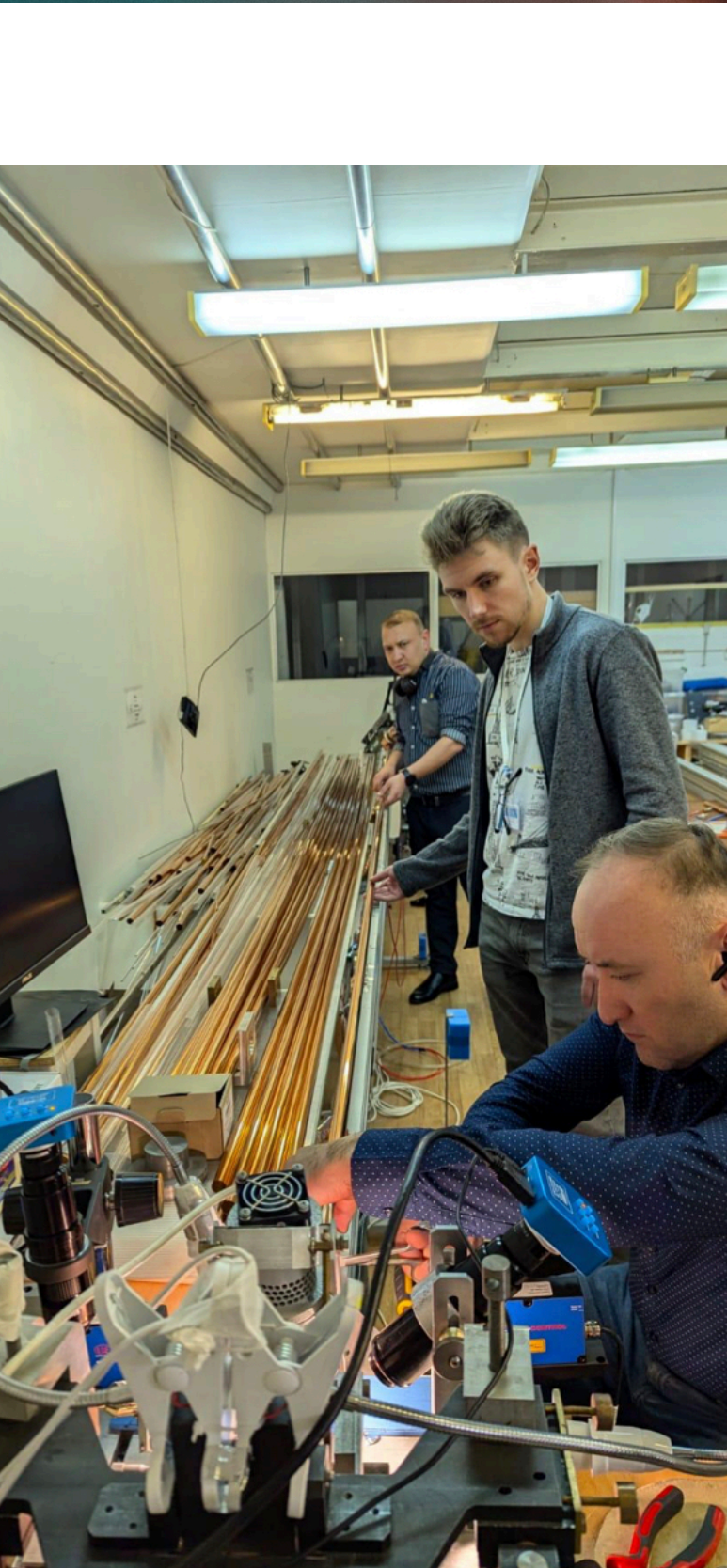


- Auxiliary measurements for astrophysics

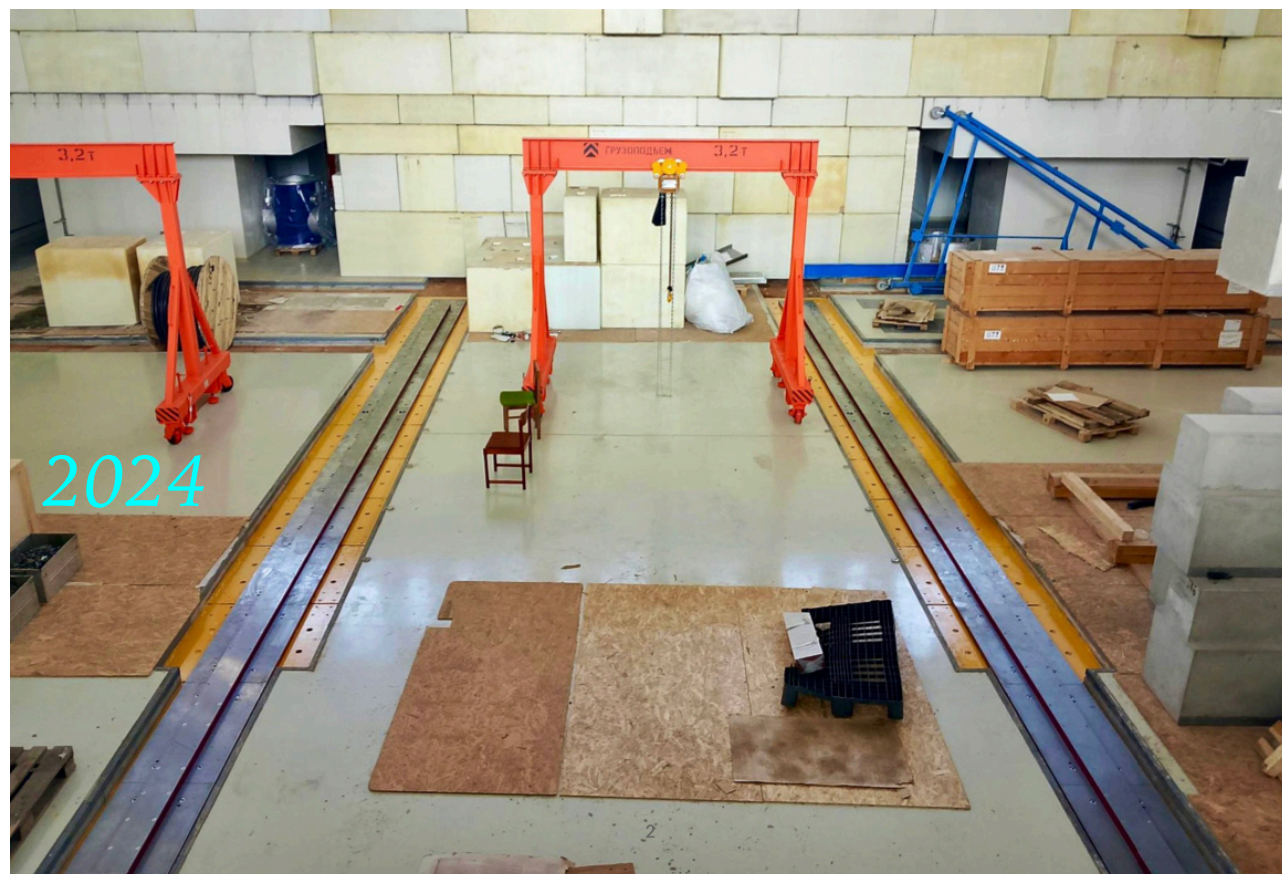
Detector prototyping



Detector prototyping



SPD experimental hall



Status of the SPD project

SPD Technical Design Report passed international expertise and published:

Natural Sci. Rev. 1 1 (2024)

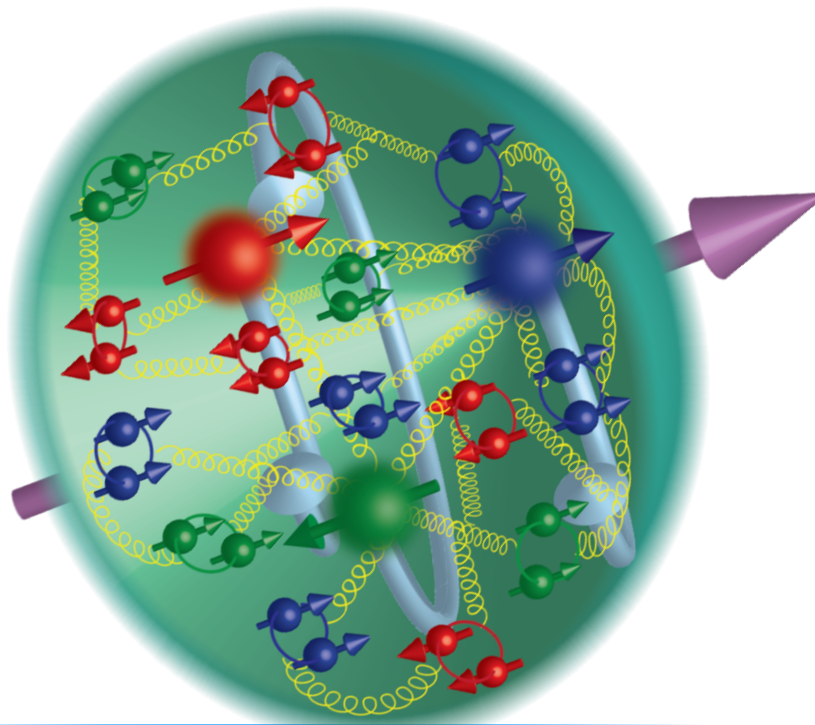
<https://arxiv.org/abs/2404.08317>

The **first phase** of the SPD project is included into the JINR's 7-year plan (2024-2030)

The **SPD collaboration** currently it consists of 36 institutes from 15 countries and more than 400 participants



Decade 2030+



*DIS: Electron-ion colliders
EIC, EicC and JLab*



*Fixed-target hadron
experiments: LHCspin, DY, etc.*



*Hadron colliders:
NICA SPD*

Summary

- The **Spin Physics Detector** at the NICA collider is a universal facility for comprehensive study of polarized and unpolarized **gluon content of proton and deuteron**; in polarized high-luminosity **p-p** and **d-d** collisions at $\sqrt{s} \leq 27 \text{ GeV}$;
- Complementing main probes such as **charmonia** (J/ψ and higher states), **open charm** and **prompt photons** will be used for that;
- SPD can contribute significantly to investigation of
 - gluon helicity;
 - gluon-induced TMD effects (Sivers and Boer-Mulders);
 - unpolarized gluon PDFs at high-x in proton and deuteron;
 - gluon transversity in deuteron;
 - ...
- Comprehensive physics program for the **first period of data taking**: spin effects in p-p, and d-d elastic scattering, spin effects in hyperon production, multiquark correlations, dibaryon resonances, physics of light and intermediate nuclei collisions, exclusive reactions, hypernuclei, open charm and charmonia near threshold, etc.;
- The **SPD** gluon physics program is **complementary** to the other intentions to study the gluon content of nuclei (**RHIC** exps, **AFTER**, **LHC-Spin**, **EIC**, **JLab exps**, **EicC**, ...)
- More information about the SPD project can be found at <http://spd.jinr.ru> .

Summary

We wait from theorists:

- *new brilliant ideas!*
- *predictions for SPD kinematics*
 - polarized **p-p** collisions, $\sqrt{s_{pp}} \leq 27 \text{ GeV}$
 - polarized **d-d** collisions, $\sqrt{s_{NN}} \leq 13.5 \text{ GeV}$
 - unpolarized **p-p**, **d-d**, and **light ions** collisions

... from experimentalists:

- *joining the **SPD project** with their experience and enthusiasm*

You are welcome!